PRACTICAL ENGINEER

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A NEW YEAR!

IT LIES AHEAD; full of new days; time for new successes; room for new growth. Opportunity to put the plant in better shape—also the man who runs it. For the best way to improve the plant is to begin on yourself. And the man who is satisfied with things as they are, never makes them better.

You find what you look for; for progress' sake, it's best to watch our own failures and other's successes. But worry is mental friction; the less friction, the less wear and the more work. Do what you can—the best you can. Learn from your mistakes—then forget them. And keep smiling.

Plan better for tomorrow by sizing up the day's work each night. Pick the things to be done; then the way to do a thing is to go and do it.

It pays to have things right; and expenditure often spells economy; but happiness and effectiveness come from right use of what we have—not from getting things we cannot use.

Forethought prevents accidents, but it's the emergency breakdown that tests the chief's mettle. Also his foresight and ingenuity.

In the rough spots, courtesy costs nothing and never offends. And in the long run, a kindness done each day is a surer investment than a bank account. Life is short even at the longest, and in the daily balance, the only real assets are; health, happiness and the love of our fellows.

And the best health, happiness and love insurance is to "be at war with one's vices, at peace with one's neighbors, and let every new year find you a better man than the last one."

Here's hoping you carry a big fat policy and realize large dividends on it during 1911.

POWER TRANSMISSION

DUTIES OF THE POWER ENGINEER do not stop with delivering power to the flywheel or generator in the engine room. Not until the power has been transmitted and delivered at the point where it is to do useful work does the duty of the engineer cease and that of the user begin. While much has been written in regard to the saving of the last heat unit in the boiler room and making the last wisp of steam from the exhaust pipe deliver its last ounce of energy before departing, most discussion has stopped at that point and has neglected to get after the foot-pounds which are going blithely to useless work of friction or otherwise, because of lack of care or understanding in laying out and operating the transmission system.

But the foot-pound wasted by the belt or line shaft or in excessive friction of gearing or in overheating of the electrical transmission lines or contacts, is a more valuable foot-pound than the one contained in the coal as it is shoveled under the boiler, because to put that foot-pound on the shaft or belt or on the electric line has cost not only 1 foot-pound of energy of the coal but from 8 to 12 foot-pounds, according to the efficiency of the apparatus which lies between the transmitting and the coal pile, so that when we waste a foot-pound of energy through a shaft out of line, a belt stretched too tight, gears improperly made or adjusted, a leaky steam pipe, or an electrical connection that has come loose or has not sufficient area, we are wasting on the average 10 times that amount of energy at the coal pile.

It behooves us, therefore, to watch carefully what becomes of this energy which has cost so much and to understand how we may best conserve the foot-pounds and the heat units which have been brought thus far.

Facts are hard things to down, and tests on the transmission of power by various methods between the engine room and the driven machinery have shown that a loss of 50 per cent is not uncommon, that 75 per cent has occasionally been found, and that from 25 to 40 per cent is the rule rather than the exception. If the average is even 30 per cent lost in transmission, at a ratio of 10 to 1 this means that 300 times the energy required to do the work at the machine has been taken from the coal because of the loss in transmission from prime mover to driven machine. While all of this cannot be saved it would seem the part of good engineering to take heed that so far as possible such loss be eliminated.

In the limits of a single issue it is impossible to treat all methods of power transmission, but those with which the engineer comes most frequently in contact are belts, with their accompaniment of pulleys, shafting and supports; rope drives, with the accompanying sheave wheels and shafting; chain drives, largely used for detail transmission; toothed gearing, in power transmission mostly used in hydraulic plants or in getting around angles; the flow of steam through piping, one of the most commonly employed systems and used inside as well as outside the power plant; the use of compressed air, to a certain extent a special system used in special industries; and electrical transmission at low voltage as used in distributing energy about a plant or factory.

Each system has its proper field, these fields overlapping to a certain extent and in many instances it seems the part of wisdom to use a combination of the systems, choosing each one for that part of the installation where it can do the best work.

While the division is only a rough approximation, it is of some help to consider the general classes of work for which the different kinds of transmission are adapted. Belting, for instance, is generally used for moderate amounts of power and over moderate distances where the shafts are either parallel or at right angles. Rope drive in its 2 forms of wire and manila rope, has 2 distinct fields, wire rope dealing with power in large amounts transmitted over comparatively long distances, while manila rope is more generally used for large power distributed within buildings or between buildings at a short distance apart.

Chain drive is usually for small amounts of power and for short distances, as from jack shaft to machine or from motor to machine, and where a positive ratio of driver to driven is essential. Toothed gearing is used more for transmission within a machine than for transmission from prime mover to driven, but has a field somewhat similar to the chain drive for direct connection of motor to driven machine and in the larger sizes for driving very heavy machinery where positive drive is essential, such as rolling mill machinery and the drive from water wheels to line shafts.

The use of steam for transmitting power is too well known to need comment. In one of the articles in this issue it is shown that this method of transmitting power is one of the most economical where pipes are properly installed and insulated, but the expense of the pipe line and the difficulty of properly supporting it and keeping the joints tight, confines its field to short transmissions and usually within the power plant.

Where heat is the essential rather than power, pipe lines are, of course, carried as far as may be necessary. The limitation of the application of power transmission by steam comes, however, rather with the utilizing devices than with the pipe system. Where power has to be subdivided into small units the low efficiency of small engines works against the use of pipe lines for transmission.

Compressed air has a certain special field. The use of pneumatic hoists and of air driven pumps and drills are the examples most frequently met. Compressed air is adapted to a large number of uses for which it has not yet been applied, and the convenience of a medium which can be exhausted without special precaution and which is harmless if it escapes at any point, are advantages well worth consideration.

Electrical transmission is, of course, the system of most recent development and the one which seems at the present outlook to have the widest field because of its great flexibility. Here, as in the matter of steam, however, the limitation becomes partly one of cost of the utilizing apparatus, and for a case where comparatively small power is split up among many machines, while the electrical transmission may be utilized to advantage for a main transmission the distribution seems rightfully to be by some form of band connection, belt, rope or chain, as may best be suited to the work. In any case the electrical transmission is usually combined at different points with some other form.

BELTING

FOR TRANSMISSION OF POWER over moderate distances within the plant or shop, belting in some form is the most frequent means used. It is simple, flexible and durable, and if properly installed and proportioned has good efficiency. Materials used for belting may be divided into 3 classes—leather, some kind of fibrous material, such as canvas or camel's hair, woven fabric impregnated with rubber, Balata or wax, and metal bands. Metal or steel belts have come into use but little in this country, although they are used considerably in Europe and have certain adventages which will be discussed later.

As between the flexible forms of belting, leather, rubber, balata and canvas, each has certain advantages in characteristics or price, and as for all other engineering apparatus, the material to be used should be carefully chosen, considering the conditions that it has to meet. With the older methods of tanning, leather belting could not be used where there was moisture to contend with, but with the modern waterproofing methods producing leather belts which can be run under water, if necessary, this objection does not hold.

LEATHER BELTING

LEATHER as used for belts comes from the hides of oxen and steers, and the hides consist of fibrous bundles with the ends sticking up, forming the grain of the leather, between which is albumenoid which is dissolved and removed by tanning. This tanning is an action of the tannin in certain barks on the hide, removing the albumenoids and other perishable material, leaving only the fibrous bundles.

There is great difference in hides as to their suitability for belting. The best hides are those from native 4-year-old steers killed in the fall. In older animals the hide is apt to be stiff and less elastic, while in the younger animals it has not reached its greatest toughness. A steer slaughtered in any month gives a good quality of hide, but in the fall the steer is in best physical condition, with hide free from pests and, therefore, all parts of the steer's body are in the best condition.

Preliminary to the tanning process those parts of the hide not fit for belting are cut off, leaving that on each side of the backbone, an average belting butt being in the region of 4 ft. by 6 ft.

Tanning

IN tanning, the hair is first removed by the use of lye made from lime which dissolves the hair sheath or follicle so that the hair can be scraped off. This has a bearing on the structure of the leather, for by studying the hair on any animal it will be seen that at certain parts of the body the hair points in a certain direction and the hair sheath has this same general slant.

On the back of a steer the hair points downward and backward, and does not reverse its direction within the distance of 18 inches from the center of the hide, which should be used for belting. It is evident, therefore, that the hair sheaths, which can be readily seen by examining a piece of belt under a microscope, should all point in the same general direction, and that there should be no reversal, as there is in the region which separates the back strips from the shoulders, flanks and belly strips.

This soaking of the skin in lye not only takes out the hair, but also swells the skin, it neutralizes the fats and makes the skin more porous for the tan liquor. After the skin is well soaked it is taken from the bath, placed over a table or bench and rubbed to remove all offal and to take away rough spots. It is then immersed in the tan liquor, which is prepared by soaking the bark of trees, those most commonly used being the white oak, the chestnut oak and the hemlock.

Oak tanned leather is strongest and most durable and should always be specified for the best grade of belting. It has a light color and is hard and firm. The hemlock gives a good tan, but not of as high quality as oak, and the leather is apt to be more of a reddish brown, somewhat the color of the inside hemlock bark.

Starting with a weak liquor the hides are moved to vats containing stronger and stronger solutions, until the process has been completed and all the albumenoids have been changed to fibrous material. They are then taken from the liquor in the tan vats and piled to drain, then rubbed with oil and hung on poles to dry. During the drying process they are moved from time to time, and this takes a long period in order to have them dry evenly and become firm, the process of tanning and drying for the best grades of belting taking about a year.

After drying, the grain side from which the hair has been removed is moistened, then rubbed down and rolled, and for the best oak tanned leather it is curried; that is, kneaded and rubbed with codfish oil and tallow, a material which gives it flexibility and a soft surface and which is one of the best dressings which can be used to keep belts in proper condition.

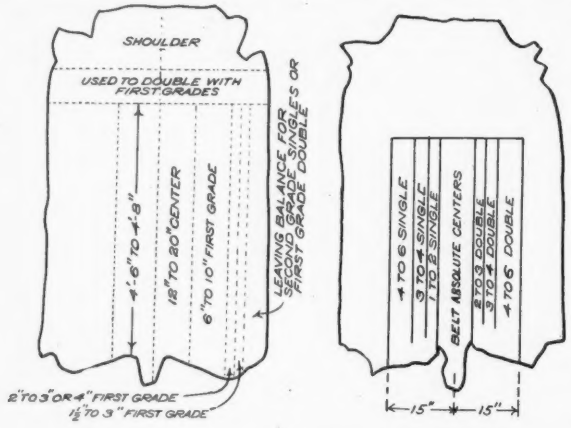
Some processes have been tried for shortening the time required for tanning leather by various chemical means, but most of these shorten the time at the expense of the strength of the leather, and as a rule leather tanned with chemicals is lighter in weight than the oak tanned, also is subject to stretching and is light in weight. This means that the leather would sell for less than if oak tanned, and to make up for this loss in weight belt is sometimes "loaded"—i.e., the pores are filled with glucose, sugar of lead or other foreign materials, which makes it appear thicker and stronger than it really is. This method of loading should not be confounded with the saturating of leather with waterproof material, which is done to make especially durable belt where moisture or water is likely to get to it.

To give the best results wide belt should be cut from exactly the center of the hide so that the spine will be the center of the belt. This will not, of course, be possible in narrow belts, but in such cases the belt should be made from strips at equal distances from each side of the spine so that it will have the same stretching quality and large wide belts should always be made of strictly centers cut with the spine in the middle of the belt, which will make it stretch uniformly on the 2 sides and run even and straight. Leather must be stretched after cutting into belting strips, in order to take out the elasticity, otherwise there will be a large amount of stretch when the belt

is first put onto the pulleys. This is done by means of clamps and screws, the leather being damp during the stretching. It is allowed to dry while stretched, then taken out of the clamps and moistened, so that it will take up a small amount of elasticity. It is evident that if a butt be slit down the middle so that on one side of the belt is the backbone and on the other side a part of the side, the stretch will be uneven on the 2 sides, as the stretch of a center is 3 to 4 in., while the sides will show from 5 to 8 in.

The belting, after being allowed to stand piled up to get this last moisture thoroughly soaked through it, is run through heavy rollers called jacking, to compress the fibers and remove all unevenness of the hide, also this will iron out any buckle.

Another process of wetting and standing is followed by the polishing, which is done by a roller in


SHOULDER
USED TO DOUBLE WITH FIRST GRADES
4'-6" TO 4'-9"
18" TO 20" CENTER
6" TO 10" FIRST GRADE
LEAVING BALANCE FOR SECOND GRADE SINGLES OR FIRST GRADE DOUBLE
2" TO 3" OR 4" FIRST GRADE
1½" TO 3" FIRST GRADE
4 TO 6 SINGLE
3 TO 4 SINGLE
1 TO 2 SINGLE
BELT ABSOLUTE CENTERS
2 TO 3 DOUBLE
3 TO 4 DOUBLE
4 TO 6 DOUBLE
15"
15"

METHODS OF CUTTING BELTING FROM HIDE

much the same way as the jacking, this polishing being sometimes used to cover up a lack of treatment and jacking when an inferior grade of leather is used in belting. The leather after cutting into strips of the right width for belt must be sorted according to thickness, also to remove any possible imperfections. It is then scarfed down and sorted up into pairs, strips from the right and left-hand side of a hide being put together, and glued up into continuous lengths.

Development of Leather Belting

WHEN belting first began to be used in the early part of the 19th century it was lapped and sewed, with no chamfer, leaving a bad bump where the joint went over the pulley. This was soon improved, but on account of trying to use the entire hide for belting there was much stretching and the belts did not wear well, and it was not until about 1860, when J. B. Hoyt began to use short lengths cut from the hide and only the back strips, not more than 18 in. each side of the center, that belting sprang into favor. He stretched his belting before sending it out and glued up the short strips with scarfed joints into long belts, thus starting the modern endless belt method.

Charles A. Schieren took up the work of belting manufacture and made several improvements, particularly in the construction of double belts, one of them being to cut holes in the belt to permit the air to escape from between the belt and pulley so as to get better contact, and another the fastening together of 2 plies with screws so as to give firm body to the belt. This style he called electric belting. Then in 1878 he introduced a leather belt made of links joined by iron rods, and running the edge of the leather against the pulley. This makes a flexible form with great pulling power, and can be made of any thickness desired for carrying heavy loads, also the flexibility avoids straining of the belt fibers in running over a pulley of small diameter.

The method of cutting belt introduced by Hoyt has been retained in the manufacture of the best quality of belting, and no shoulders, flanks or side strips more than 18 in. from the center of the hide are now used for first-class work.

Single belt consists of a single thickness of leather, the parts being run through a splitting machine, so that they will all have the same thickness, then having the ends scarfed and cemented. The double belt consists of 2 thicknesses with the flesh sides glued together, all pieces being split to the same thickness before being joined up. Triple and quadruple belts are sometimes used for large work, but the thickness becomes so great that unless the belt can be run over very large pulleys the fiber strain in bending around the pulley is considerable and such use is not advisable.

Belt Pull

BELTING is a flexible material, and in order to make it hug the pulleys tightly it is always stretched on. With new, stiff belts or belts which have become stiff from neglect, the belts do not hug the pulleys well and the tendency is to pull them tighter and tighter in order to make them drive. This results in heavy pressure on the bearings, causing excessive friction, even if not cutting, and wasting a great amount of power. It is evident, also, that if the belt be too loose much power will be wasted from slip of the belt on the pulleys, unless some means be employed to get the belt to hug the pulleys. The question then comes, what is the belt tension which will give the best results?

The old rule of thumb which held for many years in shops was that a single belt 1 in. wide at 600 ft. a minute velocity would transmit 1 horsepower. While this gave fair results, careful testing and records show that it puts too heavy a strain on the belt, thus cutting down its life, increasing the bearing friction and the loss of power. Also it is found that on a pulley of large diameter a belt can transmit more power with the same slip than on a pulley of small diameter, even if both have the same arc of contact, and as a matter of fact in most belt transmissions the pulleys are not of the same diameter and the arc of contact on the smaller pulley is less than on the large one, so that the belt works on the small pulley at a disadvantage from both causes.

For a rough figure it is, therefore, found that a single belt 1 in. wide at 1000 ft. a minute can transmit 1 horsepower economically, and Professor W. W. Bird, putting into usable form the results of experiment and test on belts, has worked out the following data:

The force which causes a pulley to turn is the difference between tensions on the 2 sides of the belt, and this depends upon the angle of wrap, the coefficient of friction, the size of the pulley and the speed of the belt. Experiments show that a stress of 60 lb. per inch of width on single thick belt will give good results, requiring only occasional taking up and giving a long life. For double belt the allowable stress is 105 lb. per inch width, and for triple belt 150 lb., provided the pulleys are not too small.

On small pulleys the tight side should have a tension not over twice that on the loose side. For medium pulleys this ratio may be 2.5 and for large pulleys 3. A thin belt gives better contact than a thick one. For this reason the double belt should not be used on a very small pulley. Many authorities give the limiting size as a 6-in. pulley for double belt and a 20-in. for triple, but Professor Bird prefers that the diameter of the pulley in feet should be at least 3 times the thickness of the belt in inches. The thickness ordinarily varies with the width, the heavier leather being selected for the wider belts and the average thickness for single belt may be taken as 3/16-in., and for double belt as 3/8-in., but one manufacturer gives the following proportions, which are probably more nearly correct for the different widths:

THICKNESS OF LEATHER BELTING							
WIDTH	1 IN.	2 IN.	3 TO 6 IN.	10 IN.	12 IN.	14 IN.	20 IN.
SINGLE	3/32	3/16	7/32	5/16			
DOUBLE	5/16	5/16	3/8	3/8	3/8	13/32	7/16

This gives us a method of proportioning thickness of the belt to the diameter of the pulley over which it is to run.

Creep

ON account of its elasticity a belt stretches as it passes over the driven pulley and contracts when it passes over the driver, that is, the tight side of the belt is under greater strain than the loose side, hence the belt stretches out as it comes onto the tight side and contracts as it comes to the loose side. We have, therefore, the peculiar condition that more length of belt comes onto the driving pulley than goes off it, while more length comes off the driven pulley than comes onto it. Obviously this results in a shifting of the belt around the pulleys in the opposite direction to which the belt is running. The amount of this creep depends upon the elasticity and the load, and in good practice it should not exceed 1 per cent.

To keep it below this value the difference in tension per inch of width of single belt should be limited to 40 lb., for double belt to 70 lb., and for triple belt to 100 lb., these figures being based on an average value of 20,000 for the coefficient of elasticity. With these conditions Professor Bird finds that running on a pulley under 8 in. diameter single belt will transmit a horsepower per inch of width at 1100 ft. velocity a minute; running on pulleys between 8 in. and 3 ft. in diameter a horsepower at 830 ft. a minute. For double belt on pulleys under 14 inches in diameter a horsepower will be transmitted per inch width at 630 ft. a minute, for pulleys between 14 in. and 5 ft. at 520 ft. a minute, and over 5 ft. at 470 ft. a minute. For triple belt on pulleys under 21 in. a horsepower per inch of width will be transmitted at 440 ft. a minute, between 21 in. and 7 ft. diameter at 370 ft. a minute, and over 7 ft. diameter at 230 ft. a minute.

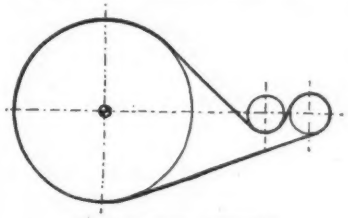
Under these conditions the proper limit for difference of tensions, per cent of creep, ratio of tensions and tension on the tight side will be observed in all cases. This is on the supposition that the belt has a contact of 180 deg. on the pulleys. In case the arc of contact is greater or less than that amount, the belt speed required to transmit 1 horsepower per inch of width for the different thicknesses of belt under different conditions should be divided by factors as shown in the Practical Tables.

To find the arc of contact of the belt on the smaller pulley of a pair, the following rule will be found convenient: Divide the difference between the diameters of the 2 pulleys by the distance between shaft centers, both values being in either feet or inches. The quotient is to be multiplied by 57 and this product subtracted from 180. The remainder will be the number of degrees in the arc of contact.

The Lenix Drive

THIS consists of a jockey pulley which rides on the loose side of the belt, on top, near the smaller pulley. It is carried on an arm that has a weight at the end so that it floats on the belt. The advantage is that with a large load the belt is stretched to a greater degree and gives more slack, which the floating pulley takes up as a wrap around the smaller pulley, thus overcoming the effect of centrifugal force. On short drives, especially, this works well, 20 in. between the rims of wheels having been found ample for a drive and the belt ¼ as large as with the straight drive having been found sufficient. It is also possible to use a high ratio of diameters, as high as 30 to 1 having been successfully run.

Based on this transmitting ability for belting, the Table Horsepower of Belts found in the Practical



THE LENIX SYSTEM

Tables has been prepared and the horsepower for any belt can be found by the following rule: For the given belt and pulley multiply the horsepower as shown in the table by the number of thousands or hundreds of revolutions at which the pulley runs by the width of the belt in inches and by the correction factor for the arc of contact.

Centrifugal force plays a considerable part in the action of a belt, particularly if it is large and heavy. This force tends to throw the belt away from the pulley and thus lessens the friction, and above certain speeds the reduction of friction by the centrifugal force is greater than the gain from the increased speed. The limiting value is usually placed at between 4,000 and 5,000 ft. per minute velocity for the belt and 4,250 is a safe and conservative limit to set. The second column in the table shows the velocity at which a belt will be running on any given pulley at 1,000 or 100 revolutions per minute, as specified in the table, and this velocity will increase directly as the number of revolutions. Care should be taken, therefore, in proportioning any drive that this velocity times the number of thousands or hundreds of revolutions, as the case may be, does not get above the limit set of 5,000 ft. a minute, and preferably should be kept below 4,250.

Thus for a 6-in. double belt to run on an 18-in. pulley at 450 r.p.m. with a contact of 150 deg., we find in the column for double belt opposite 18 in. diameter 0.923 hp. for 1 in. wide at 100 r.p.m. Then at 450 r.p.m. and 6 in. wide, $0.923 \times 4.50 \times 6 = 24.95$ hp. for 180 deg. contact, and the correction at 150 deg. is 0.91, hence $24.95 \times 0.91 = 22.65$ hp. The velocity will be $380 \times 4.5 = 2160$ ft. per min., which is well inside the safe speed.

Other Belt Power Rules

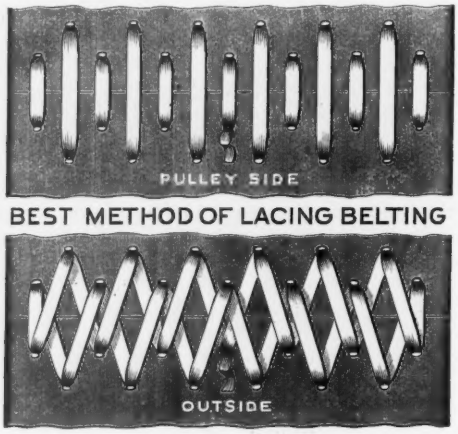
WHILE Professor Bird's work has been taken as the basis for the table because it is the simplest embodiment of modern knowledge into a working rule, the practice of other engineers is worthy of attention.

Based on a long series of records and careful tests, F. W. Taylor and C. G. Barth have adopted 240 lb. per square inch of belt section as the correct value for leather main belts and 160 lb. per square inch as the tension for belts on countershafts and other drives where the belts cannot easily be shortened. While the tensile strength of best leather belting is about

SIMPLE LACING FOR NARROW BELTS

4000 lb. to the square inch, the strength at the glued joints is not over 0.1 of this, and with laced joints or metal fasteners is even less, so that the values as adopted are reasonable figures.

A simple rule which will give roughly the approximate power of a belt, but which does not, of course, take any account of the thickness of the belt or the pulley over which it runs, is as follows: For single thick belt the horsepower transmitted equals the diameter of the pulley in inches times the revolutions per minute, times the width of the belt in inches, divided by 27.50, and for double belt the same expres-



DOUBLE ROW LACING FOR HEAVY BELTS

sion except that the divisor is 19.25. This is for 180 deg. arc of contact, and for a less arc of contact results should be multiplied by the factors as given in the Practical Tables.

The effect of running a belt vertical on the pull of the belt is a point on which authorities differ. Barth says that this effect is not so great as has been supposed, while Sutcliff states that a vertical belt will transmit 18 per cent less than a horizontal of the same dimensions. It is reasonable to suppose that since the weight of the belt tends to draw it away from the bottom pulley, there will be a considerable reduction in the power transmitted.

Also there will be a difference in the power depending on the surface against which the belt runs as well as on the material of the belt. The co-efficient of friction when running depends also on the speed at which the belt is running, but the way in which this coefficient varies cannot well be determined. The coefficient when standing still is as follows: For leather on iron, dry, 0.42; when wet, 0.36; when greasy, 0.23. For leather on a leather covered pulley, 0.45. Cotton on an iron pulley, 0.3; rubber on an iron pulley, 0.45; leather on wood, 0.38; leather on pulp, 0.29. These are not the coefficients when the belt is running, but give an idea of the relative values for different surfaces.

Coefficient of Friction

AS a result of his investigation on the coefficient of friction and its variation with velocity, Barth gives the following rule: Subtract from the tension on the tight side 140, and add ½ the tension on the loose side; multiply this by 0.54 and divide by the velocity in feet per minute plus 500. In deciding what the tensions are it has been considered that the sum of the tensions when standing idle is practically equal to the tension of the tight side plus half the tension of the loose side when running, and this is taken at 240 lb. per sq. in. for main line belting, and 160 lb. per sq. in.

STAGGERED LACING FOR HEAVY BELTS

as a minimum for countershafts and other places where the belting cannot readily be tightened. These values agree very nearly with those given by Professor Bird, which are shown in the Practical Tables.

Length of Belts

WHENEVER possible the required length of a belt should be measured by passing a steel tape around the pulleys, as a cloth tape or cord will stretch and thus give unreliable values and computation is always liable to error. Where, however, it is impossible to measure the length, it can be figured for an open belt as follows: Add the diameters of the pulleys, divide by 2, multiply by 3.2 and add twice the distance between centers. This gives practically correct results for pulleys of approximately the same diameter and for a fairly long distance between centers.

Where the pulleys have great difference in diameter or the centers are short, or the belt is crossed or of irregular run, this cannot be relied upon, and if measurement cannot be taken, the only safe way is to lay out on a drawing to scale carefully the positions of the shafts, put in the pulleys and measure the length on the drawing.

The best practice calls for a belt bench having pulleys so arranged on movable centers that the belt can be cut off under the required tension to the correct length. When this cannot be done, from ¾ in. to 1 in. should be subtracted from the measured length of the belt for each 10 ft. of length, and this same amount can be cut off when retightening a belt.

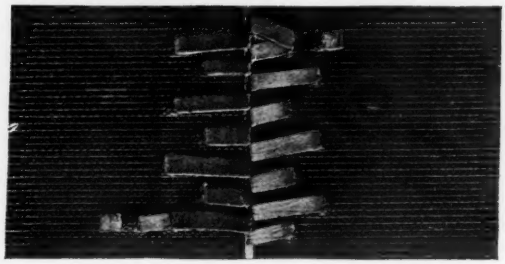
To find the length of belt in a roll, add to the overall diameter the diameter of the center hole and divide the sum by 2; multiply this by 3 1/7 and by the number of laps. This gives the length in inches and dividing by 12 gives it in feet.

The ratio of pulley diameters in belt transmission should not be over 6 to 1 unless some special provision is made for increasing the arc of contact on the smaller pulley, such as the use of an idler or the Lenix drive, and the face of the pulley should be made 1 in. wider than the belt.

Crowning the pulleys to keep the belt on, that is, making the diameter larger at the middle of the pulley than at the edges, is common practice, but, of course, produces extra stretch at the center of the belt, and the crowning should be made as small as possible. Usually this is made not over ⅛ in. for narrow pulleys and ⅛ in. per foot of width for wider ones.

Splicing Belts

UNDOUBTEDLY the best method of joining the ends of belts is by a cemented joint, the ends being scarfed so that the belt will be at all points of the same thickness, and then well glued together. In making such a splice, the ends should be cut perfectly



HINGE LACING WITH DOUBLE ROW FOR SMALL PULLEYS

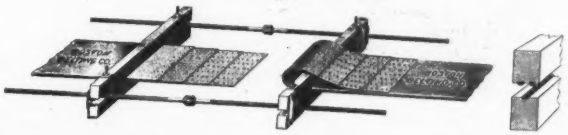
square, the scarf then made an even bevel for the required length, the belt laid on a board 1 in. longer and ½ in. wider than the joint and clamped there, the 2 parts of the belt being brought into exact line. The 2 ends should then be tacked to the board back of the joint, the joint opened up, served with glue, placed together and clamped by another board placed on top and heavy hand clamps. The belt should be allowed to stand in the clamps for 3 or 4 hours and should not be put under tension for at least 5 hours after gluing.

The length of a splice on double belt up to 10 in. wide should be 10 in. On belt 10 to 18 in. wide, make the length of the splice equal to the width of the belt, and for belts above 18 in. wide the length is 18 inches. The glue should be applied hot and can be made waterproof by adding a little bichromate of potash just before using. In the case of single belts the splice should be so arranged that the tip follows on the side next the pulley, the grain side being, of course, used against the pulley.

On double belts the splice should be arranged so that the tip follows on both sides of the belt, one end being scarfed as a wedge and the other as a V. Where it is impossible to use a cement splice, lacing or metal fastenings must be employed. A hinge lacing of some form is usually the most satisfactory, particularly where the belt runs over a pulley of small diameter. This may be made either by the use of leather lacing, as indicated in the figure, passing the lacing from one side of the joint to the other between the ends of the belt, or it may be made with a wire lacing having a separate wire laced into each end of the belt, forming one side of a hinge and the 2 parts of the hinge joined by a rawhide pin. This form is best done on a belt lacing machine and when it is used the belt should be cut short enough to take care of the stretch and a distance piece 6 in. long put in when the belt is new. This distance piece can be changed for others of 5, 4, 3, 2 and 1 in. length, as the belt stretches.

Various methods of lacing belts have been devised, a number of which are shown herewith and the conditions for which each one is suitable are given with the illustration. In arranging the holes for lacing it should be remembered that several small holes will hold better than a few large ones, since the load which each hole will carry is about 500 lb.

For a 3-in. belt use 4 holes in each end, 2 in each row staggered. For a 6-in. belt use 7 holes in each

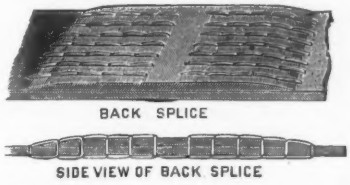


BELT CLAMP FOR MAKING SPLICES

end, 4 in the end row and 3 in the second row. For a 10-in. belt use 9 holes in each end, 5 in one row and 4 in the other. The holes should be ¾ in. from the sides of the belt and the first row ⅞ in. from the end. The second row should be 1¾ in. from the end. Of course, for small single belts 1 row of holes is frequently sufficient where the load is light.

In lacing, care should be taken either that the lacing runs straight on the pulley side or else that it is symmetrical with respect to the center, so that there will be no tendency of the joint to throw the belt to one side or the other of the pulley.

Metal fasteners of different forms are used, most of them being patented specialties and described under



BACK SPLICE FOR WIDE RUBBER BELTS

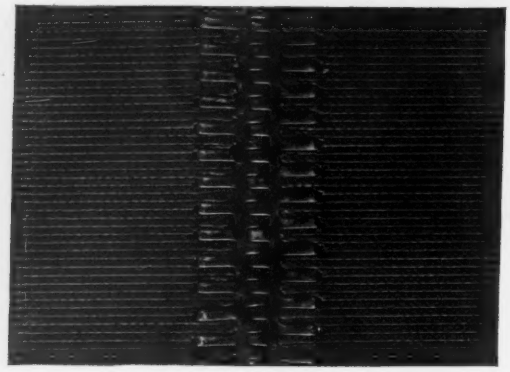
the names of the manufacturers. One authority gives as the holding power of different forms of joints, for cement 400 lb. per sq. in., for well laced joints 300 lb. per sq. in. and for metal joints 250 lb. per sq. in., but these figures have not been verified and in any case, any one of them is greater than the most economical tension for a belt.

When using metal fasteners, care should be taken that the points project well through the leather and are turned over and sunk into the belt so that they will not strike on the pulley, as otherwise there will be slip on the pulley when the joint passes it, producing irregularity in the speed.

When lacing belts the size thong to be used is as follows: For small belts, ¼-in. thong; for 4 in. to 8 in., ⅜-in. thong; for 8 in. to 15 in., ½-in. thong, and over 15 in., a ¾-in. thong. Usually the holes are made oval in shape, with the long axis lengthwise of the belt. This is particularly necessary where a belt is to be double laced, as indicated in some of the methods shown.

Belt Specifications

TO secure the best quality of leather belting the following specifications will be found useful and safe. The belts should be of the best oak tanned leather, with short lap, cut from within 18 inches of the center of the butt, and with no piece over 4 ft., 6 in. long. It should be made by long process tan, and without the use of acid. It should be of uniform thickness and width and the tensile strength not less than 4200 lbs. per sq. in. for leather or splice. The elongation



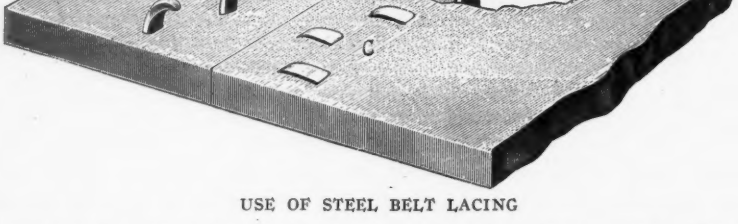
HINGE JOINTS WITH ALLIGATOR FASTENER AND WITH

should be not over 12.5 per cent in 2 in., taken 1 in. on either side of the break, and for double, triple or quadruple belt there should be no crack between the layers under 2500 lbs. per sq. in. strain.

In weight the heavy belts should be from 17 to 19 oz. per sq. ft., medium 15.5 to 16 oz., and light weight 14 to 15.5 oz., and not more than 10 to 13 per cent of weight should be lost by gasoline treatment to remove the filling. This does not mean that filling is necessarily an evil, because in the best belting it is used as a means of waterproofing.

The belts should run straight, and give no trouble if the shafts and pulleys are right. Pulleys should be 25 per cent wider than the belt, and a tension of 100 lb. per sq. in. should be put on the belt at rest, the centers of shafts being not less than 20 ft. apart if possible.

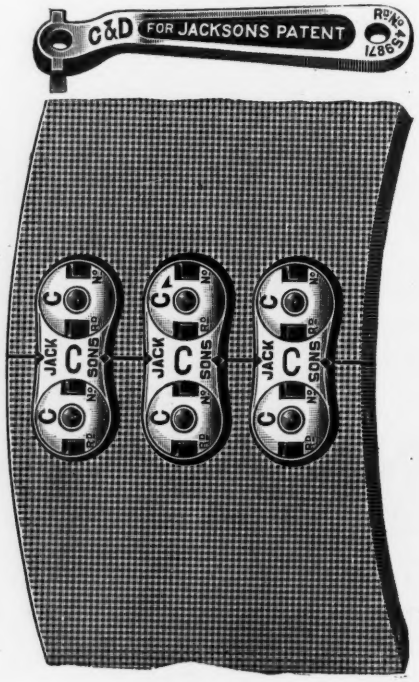
One horsepower should be transmitted for 80 sq. ft. of double belt or 160 sq. ft. of single belt passing



USE OF STEEL BELT LACING

over a pulley per minute; this number of sq. ft. being found by multiplying the width of the belt by the velocity in feet per minute. Taken in another way, single belts should give 1 hp. for 2000 ft. per minute per inch of width, and double belts 1 hp. for 1000 ft. per minute per inch of width.

In installing the belts, use a 6 in. takeup piece in new belts and set in shorter pieces as the stretch comes on, using a wire lace with hinge joint and



THE JACKSON FASTENER

rawhide pin. Where stretch can be taken up by idlers or movable shafting an endless belt should be employed.

CANVAS BELT

THIS is ordinarily made from cotton duck, although hemp and other fibrous materials are sometimes used. A 30 or 32-oz. duck is prepared by stretching and rolling and the edges are then folded in to the middle, thus giving 2 thicknesses of duck. For a 3-ply belt a single thickness is cemented on top of the double belt or for a 4-ply belt 2 double thicknesses are prepared and cemented to-

THE BELT STUD

gether. In the best qualities the plies are stitched as well as cemented, and the fabric is made from long fiber uncompressed cotton, especially hard woven and tested to 1500 lb. per square inch.

This duck is treated with a special saturating material which is worked entirely through the fabric to

soften it, preserve it and to give cohesion, the material used by different manufacturers varying according to their experience. Such belting is made in 3, 4, 6, 8 and 10 ply, the 4-ply, which is the most common thickness being equal in strength to single leather belting, 6-ply to heavy single, 8-ply to double leather, and 10-ply to heavy double leather.

For the best work pulleys used with canvas belting should not be smaller than 4 in. diameter for 4-

SEWED LAP SPLICE FOR FIBROUS BELTS

ply, 6 in. for 6-ply, 8 in. for 8-ply, and 10 in. for 10-ply, and no cotton belt should be run on a pulley less than 3 in. in diameter. For best results cotton belts should be run at not over 3500 ft. a minute, 4000 ft. being the limit.

For finding the horsepower of canvas belting, the Gandy Belting Co. gives the following rule: Multiply the belt speed in feet per minute by the width of the belt in inches and for 4-ply belting multiply by 40, for 6-ply belting by 60, for 8-ply belting by 80 and for 10-ply belting by 100, and divide the product thus obtained by 33,000. The horsepower for a 4-ply cotton belting is given in the practical tables of this issue and the power for any other thickness of belting can be found by dividing the values of the table by 4 and multiplying by the number of plies.

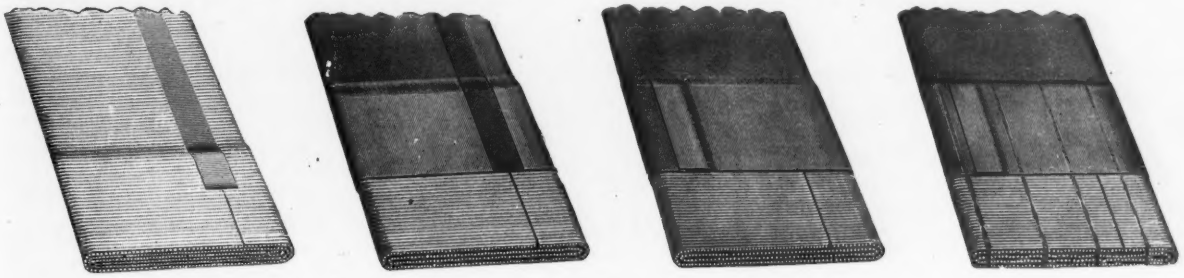
Treatment of cotton belting is much the same as for leather. Where subject to dampness the belt should be rubbed down occasionally with castor oil and if the situation is very dry and warm a dressing of raw linseed oil will help keep the belt supple. Rosin should never be used on cotton belts.

RUBBER BELTING

THE basis of rubber belting is what is known as friction, which is a duck impregnated with rubber and partly vulcanized. Different weights of duck are used, according to the quality of belt made, but as a rule a 30-oz. duck is used as the foundation. Building up the belt is much the same as for canvas, a 2-ply belt being made by folding the edges on the center and vulcanizing a strip of rubber along the joint, this joint being run always on the outside of the belt; 3-ply is made by folding a thickness of the friction inside the edges, the joint being covered with a strip of rubber while 4-ply is made by folding in the edges of 2 strips to the center and then cementing the 2 folded strips together. A ply or layer of the friction is about 1/12-in. thick, but in the calendering or rolling down and vulcanizing the belt is somewhat compressed so that a 4-ply belt is practically ¼ in. thick. Rubber belt of common construction will weigh about 12 to 15 lb. per ply per inch of width.

As to power transmitted, a 3-ply has about the same capacity as a light single belt, a 4-ply as a heavy single, 5-ply as a light double, and 6-ply as a heavy double. Assuming the 4-ply, which is the most common thickness, as 1, it will safely carry 1 horsepower at 735 ft. per minute belt speed for each 1 in. in width. This is figuring on a tension of 65 pounds per inch. For a 3-ply belt 45 lb. is the safe tension and it has 0.7 the horsepower of a 4-ply belt. A 5-ply will carry 85 lb. or 1.3 of 4-ply; 6-ply will carry 105 lb., equal to 1.6 of the 4-ply; 7-ply will carry 125 lb., equal to 1.9, and an 8-ply belt will carry 145 lb., or 2.2.

Rubber belts are very flexible, hence have gripping power on the pulleys which may be increased by the use of a special lagging on the pulley surface. Pulleys should be as large as possible, because bending a rubber belt, particularly if it be a thick one, around a small pulley causes forward and backward motion between the upper and lower plies, rubbing off the coating of rubber from the duck near the center plies. For 4-ply, use 24 in. or larger; for 5-ply, 30 in.; for 6-ply, 36 in.; for 7-ply, 42 in.; for 8-ply, 48 in.



METHOD OF CONSTRUCTION OF RUBBER BELTS

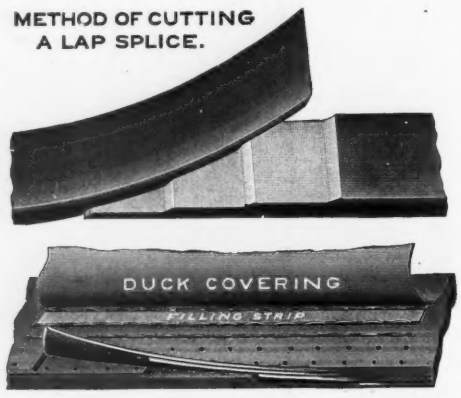
In cutting rubber belt a stretch of ⅛ in. per foot should be allowed for, and in fastening this belting either lacing or clamps must be adopted. A cemented lap splice may be made by the use of rubber cement, but this should always be stitched, as the rubber alone has not sufficient tensile strength to hold the belt together.

If a lap splice is made the length should be as follows: For 8-in. belts, 24 in.; for 12-in. belts, 36 in.; 16-in. belts, 32 in.; 24-in. belts, 36 in.; 30-in. belts, 40 in.; 48-in. belts, 48 in., the splice being made by cutting each ply off for a certain length and letting a ply on the opposite end of the belt be cut long to match this as indicated in the figure. Both surfaces are covered with rubber cement and clamped together, then carefully punched and sewed with a narrow lace leather. Such a lap splice is protected by means of a thin duck covering cemented on. Obviously rubber belt is desirable where the belt must run in a moist place, but is not suitable where any mineral oil can reach it, as this rapidly rots the rubber covering.

Rubber grips a metal pulley better than leather, but it is not safe to calculate on a higher belt pull for slip between the pulley and the belt wears the rubber covering and this causes rapid deterioration. In proportioning rubber belting it is better to have it wide and thin rather than narrow and thick, because the rubbing between plies will be less. A belt speed of 4000 ft. a minute may be safely used, but the belt

should be of sufficient width and thickness to transmit the required power easily. Large pulleys should be used and long belts are preferable to short ones. Rubber belting may be run at high speed with good results. The power of 4-ply belting is shown in the practical tables and the amount of power which can safely be transmitted is almost exactly in proportion to the number of plies.

In caring for rubber belts, to keep the surface in good condition a dressing is made of equal parts of



CUTTING, SEWING AND COVERING LAP SPLICE ON RUBBER BELTS

red lead, black lead, French yellow and litharge mixed with boiled linseed oil and Japan enough to make it dry quickly. This should be applied with a brush and the effect is to give a finely polished surface. It will also help coat the surface of the belt in case any of the rubber coating gets peeled off. If dust or dirt gets on a rubber belt, causing it to slip, the surface should be lightly moistened on the side next the pulley with boiled linseed oil, but animal oils or mineral oils should never be allowed to reach the belt.

BALATA

THIS is a belting with cotton canvas base impregnated thoroughly with balata, which is a substance prepared from the milk of the Boela tree; the solution is forced into the meshes of the woven goods. Balata is not vulcanized as is rubber, but the material is thoroughly saturated with the dissolved gum, and the outer surface is finally dressed with a thin coat to give the belt a finished appearance rather than for any other purpose. The grip of balata belting on the pulleys is not injured by the wearing away of this surface coating, nor can moisture penetrate the belt, even though the surface coating should be worn off, for the balata itself is waterproof and prevents the entrance of any liquid into the meshes of the canvas.

It has the peculiar quality that when slipping on a pulley the heat caused by friction softens the balata gum, thus giving the belt a greater grip on the pulley. The duck used for the basis of balata belting is of extremely compact firm texture and is made from a yarn that is stretched as it is woven. This results in a belt with the stretch largely taken out of it and also in a construction such that a wide balata belt may be cut down to a narrower width and will run perfectly. Three-ply balata belting is the equal in power transmission of ordinary single leather belting and 5-ply of ordinary double leather.

Such belt does not stretch greatly and when cutting new belt an allowance of 1 per cent of the length is sufficient to take out the stretch. This belting is not suited to extremely high temperatures, as under certain circumstances the gum will soften so as to make the running of the belt uncertain.

Joining Belts

IN joining canvas belts the holes for lacings are usually made by an awl which forces the fibers apart rather than cuts them, as the cutting of fibrous material weakens the end of the belt. For a belt with several plies it is better to use a step splice, plies being cut away step by step so that the 2 ends match each other, and then stitched with rawhide thong. The method for joining canvas is practically the same as that recommended for rubber belts and where the step splice is not desired the hinge form of joint is recommended, using a rawhide lacing and spacing the holes in 2 rows as shown in the illustrations.

Where the step splice is used, the holes should be made from 1 to 1¼ in. apart, not closer to the edge than ½ in., and the rows of stitching should be from 1 to 1½ in. apart. Lacing for belts under 3 in. should be ¼ in., from 4 to 8 in., 5/16 in., and for belts of greater width, ⅜ in. A hinge joint made with alligator fastener, as shown, is satisfactory, the prongs being driven into the belt and clinched on the opposite side, leaving openings through which a rawhide pin is inserted. A wire lacing hinge joint made by the Jackson Belt Lacer Co. is also suitable for canvas or balata belt and for heavy belts the Jackson screw fastener may be used. The Crescent fastener is satisfactory, plates being used with split copper rivets.

For rubber belting the step splice laced with narrow lace leather or wire may be used, rubber cement being spread on the joint surfaces. After the stitching is done the spaces between the rows of sewing should be coated with rubber cement and strips of rubber-coated duck put on, then a duck covering cemented over the whole joint, the strips and cover being firmly rolled or pounded onto the belt. A diamond lap splice is sometimes used, also for wide belts a back splice which is much the same thing as a butt joint for boiler plate with a single cover. The length of the cover plate is usually about 1½ times the width of the belt. The lap splice, either of straight or diamond form should always be used in a belt 18 in. or over in width, and for the diamond splice dimensions should be as follows: From 6 to 9 in. width, 24 in. long; 10 to 15 in. wide, 30 in. long; 16 to 24 in. wide, 36 in. long; 26 to 32 in. wide, 42 in. long; 34 to 48 in. wide, 48 in. long, the length to be divided into 3 equal parts as indicated on the finished splice.

Care of Belts

AS belting is one of the expensive items in a belt-driven plant, systematic care will result in a considerable decrease in the belt expense. Where there are many belts a regular belt room with outfit for repairing is well worth while. This should be some 10 by 25 ft., centrally located and stocked with the different sizes of belts used in the establishment and provided with facilities for making cement joints. A 100-ft. steel tape is necessary for determining the length of belts, also the necessary tools for making cemented joints and for trimming belts, including a belt trim-

mer, a 1⅝-in. wide smoothing plane, pliers, clamps, punches, straight edges, a press for making joints, lacing cutters, try-square, etc.

Careful record should be kept of the history of each belt, showing its width, thickness and length, where it is located, when it was first put on, and the days when it was put on, when it is taken off, and when it has been cleaned or dressed. Belts should be regularly inspected to see whether they have stretched beyond the economical limit so that they are slipping excessively or are not pulling the load that they should. They should be carefully cleaned and dressing applied at regular intervals to keep them flexible and keep the surfaces soft. The tension should be kept

BELTING CHART

Floor_____
Room_____

(RECORD OF EACH BELT TO BE KEPT FROM DAY OF ITS INSTALLATION)

_____Foreman

Character of Work	OLD BELT						Date Installed	NEW BELT							Remarks
	Mfg'r	Type	Size	Ply	Length of Life	Remarks		Type	Size	Ply	Taken Up	Increased Efficiency No. of Days	Increased Efficiency Per Cent.	Date of Removal	
											1 2 3 4				
											1 2 3 4				
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SAMPLE BLANK FOR BELT RECORD DEVISED BY THE NEW YORK LEATHER BELTING CO.

in the region of 100 lb. per inch of width for double belting when at rest, and this can best be measured by attaching belt clamps having spring balances on the side screws and taking the tension off the belt at some point to see what it tests up. If by extra flexibility the needed pull to transmit power can be had at a less tension, so much the better, as it will lessen the bearing friction.

Rosin should never be allowed to get onto belts nor should mineral oil. In case oil or grease does get on belts they should be cleaned with gasoline and after that belt dressing or neats foot oil should be worked in to give them the required elasticity. Treating new belts with a dressing consisting of equal parts fish oil and tallow before using will give them longer life and better pulling power.

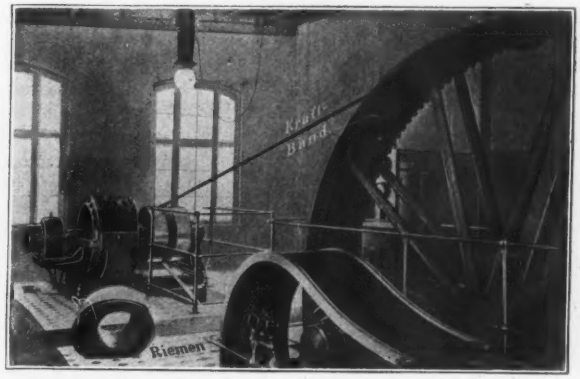
The hair side should always be run next the pulleys and care should be taken to see that the pulleys are in line and in good repair, as a rough surface on a pulley will ruin a belt in a short time. Where belts are so situated that persons are likely to get against them, guards should be provided for the protection of belts as well as of people, because there is always temptation for the thoughtless to hold something against the edge or the surface of a belt, and a belt may be quickly ruined or greatly damaged in this way. Also the danger from a belt catching the clothing of a person and drawing him into the drive is considerable and a belt guard avoids this.

STEEL BELTS

THESE have not been used in the United States but are becoming common in European practice. The advantages of the steel belt are that it may be run at a high speed without the effect of centrifugal force becoming noticeable and that a narrow belt may be used to good advantage. In the latest practice the ends of the belt are joined by soldering and clamping to the halves of a lock, these 2 halves then being joined by means of screws.

The illustration shows the method, the ends of the belt being brought between blocks and the 2 parts of the lock soldered in place and also clamped by the small screws. The clamp if in 2 parts is then joined by screws.

Steel belts run well for a time on cast-iron pulleys, but there is a tendency to polish the pulley surfaces and it is found that better results are obtained by covering the pulley with a thin layer of cork glued on



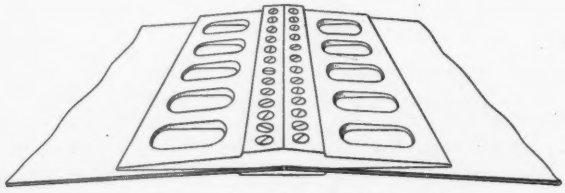
EXAMPLE OF STEEL BELT INSTALLATION

canvas and the canvas cemented to the pulley; that there is no slip is shown by the fact that the cork does not wear away.

The coefficient of friction varies from 0.27 up to 0.51, the former being at a speed of 3000 ft. a minute

and the latter at 5800 ft. An advantage of the steel belt is that is does not stretch nor does it seem to wear appreciably. The width used is 0.1 to 1/3 that for other types of belts to transmit the same amount of power and belt speeds up to 10,000 ft. a minute may be employed with success. Care must be taken, however, to safeguard the belts so that no one can get against them, as the rapidly moving thin edge of the belt acts like a very keen knife.

In thickness the belts are from 0.008 to 0.036 in. Some examples of belt transmission which have been recorded, are a belt 0.9 in. wide and 0.0118 in. thick



CLAMP FOR ENDS OF STEEL BELTS

on a 49-in. pulley had a tensile pull of 7112 lb. per square inch and with a pull of 84 lb. per inch of width transmitted 145 hp. A belt drive for a 200-hp. engine at 150 r.p.m. running on pulleys 148 and 32 in. in diameter required a 4-in. belt 0.02 in. thick at 5300 ft. per minute belt speed. A belt on a 125-hp. gas engine running at 186 r.p.m. was 4 in. by 0.02 in. and running on 127 and 36-in. pulleys at 6200 ft. per minute. A 60-hp. unit at 180 revolutions ran on pulleys 100 and 24 in. diameter, was 2⅝ in. wide by 0.012 in. thick; and a 50-hp. drive at 110 r.p.m. ran on pulleys 55 and 46 in. diameter was 4 in. by 0.044 and ran 1600 ft. per minute.

MAKING ORDINARY BELTING WATERPROOF

By A. E. Michel

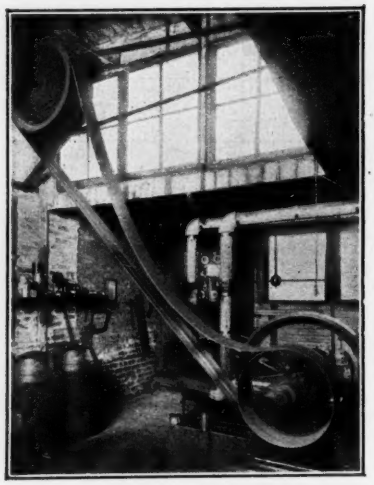
IT FREQUENTLY happens that belts previously running in dry surroundings are subjected to changed conditions that demand preservative treatment against moisture to save the expense of out and out new equipment.

Dampness is frequently met with in ordinary plants and prevails in textile mills, laundries, paper mills, etc., or with belts exposed to weather, and especially in tropical climates. The wet Monday morning is dreaded because the belts have been affected by the damp air and all too tight. The combination of excessive moisture, whether constant or intermittent and variable load is bound to make the life history of the belt short and strenuous. Without careful attention, the fabric and joints of an ordinary belt would break down in such service and invite slipping, running off the pulleys and sudden unexpected repair delays and expense.

Effective protection against moisture at the smallest possible expense is therefore essential, and many have found it profitable to use ordinary leather belting filled with some preservative that prevents the water from getting into or remaining on the outside of the belt. Where the belting is so treated, damp days or conditions have no influence whatever.

As an instance where such treatment saved considerable money, much of the belting in the plant of the Eagle Paint and Varnish Co. of Pittsburg is regularly treated because of the moisture which it receives during wet weather. In 1908 some of the belting was submerged under water for 6 hours. Formerly the wet sections of such belts would have to be cut out and replaced, but before a recent flood the belts had been filled with Cling-Surface and came through intact. After cleaning they were ready for business and good as ever. Cling-Surface, by the way, is primarily used to increase the power output, which it accomplishes by improving the bending qualities of the belt interior and softening the contact surface. Incidentally the belt is waterproofed except for the cement, which is so surrounded that only the thin edges are exposed. Under this condition the laps would not come apart unless immersed in water for several days and in damp or steamy atmosphere the glue would not be affected at all. A treated belt that has been sewed or riveted instead of glued would, of course, be absolutely waterproof throughout and could run submerged in a water pit.

That the above is more than mere theory was nicely proven in the woodworking shop of H. A. Lancaster, Sterling, Pa., where the belts had orignally been treated because they always slipped and ran off just when rush jobs came. A flood at this plant buried the belts for 4 days in sand, sawdust and water, but



EFFECT OF CLING SURFACE ON A VERTICAL BELT

the preservative treatment had rendered them immune even to this severe test.

Years ago in Buffalo at the Erie Railroad dry dock a shed-like building, in which were a lot of woodworking machines, was unroofed by a storm and the rain poured in all night on the machines and belts. The belts had been treated with a preservative, but the superintendent had misgivings. When he looked the belts over they seemed all right and were started up. They had not been affected at all.

In the plant of the North Milwaukee Light and Power Co., water often cannot be kept out of the flywheel pit, but by keeping the main belt properly treated it runs well and shows no undue disintegration.

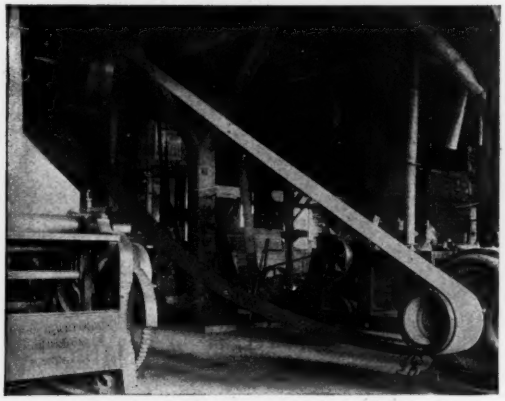
A very good comparative test was made at the Newport News (Va.) pumping plant between 2 belts doing identically the same work on belted pumps, one belt being subjected to waterproofing treatment and the other not. These belts are 10 in. wide, on 30-ft. centers and were put in service the same day.

The untreated belt was subsequently found completely rotted and condemned as unsafe to run, while the other was soft as kid and in perfect condition.

Unpainted cotton belts are, of course, troublesome, because they stretch and contract like a clothes-line with every atmospheric change. When they are properly treated they are made absolutely waterproof, because there are no glued laps. The preservative readily penetrates between the fibres, mats them together, makes a heavier belt, more dense, with less stretch, with no possibility of cracking and absolutely waterproof. This is a good belt and a cheap belt for many purposes. The well stitched canvas belt, made of plies of canvas is preferable to the woven webbing form of belt, as it stretches less and has more weight and density when waterproofed.

Camel hair belts are just the same as the unpainted cotton belts of the woven variety, but are of course a much better belt to start with and can be made equally waterproof.

Rubber belts are only approximately waterproof after they have been run for a short time, as they develop pin holes which admit the moisture but do not admit of its evaporation. A preservative should be used to fill up these holes and the belt will then be really waterproof.



TOP DRIVE BELT RUNNING LOOSE

The possibilities of belt treatment as outlined are shown in the accompanying photographs taken in places where the conditions must necessarily be very severe. All of these belts have been filled with Cling-Surface and tell their own story.

It should be remembered that the belt as a transmitter of power is as important as any other part of the mechanical system. No man would expect an engine to run indefinitely with no other attention than opening the throttle, nor should he expect more of the belting, especially where it works under adverse conditions.

ALBECO LAMINATED BELTING

American Laminated Belting Co., New York, N. Y.

IN THIS BELTING the leather is cut into strips, which are fastened by lacings, side by side, and run so that the cut edge of the leather forms the belt surface. Each strand is cut separately from the hide and is stretched separately, and any unevenness of the assembled belt is removed by scarfing both surfaces and treating with a special dressing after the belt is assembled. The finished belt is then stretched finally over high crowned pulleys so that every strand is a transmitting unit in itself. The advantages obtained by this construction are great flexibility, wear against the ends of the fibre resulting in great durability, and high transmitting power. Because of the flexibility, the belt hugs the pulley, and because of its sidewise flexibility it runs true on the pulleys. Some idea of the elimination of the excessive stretch from Albeco

ALBECO LAMINATED BELT, INDICATING THE MANNER OF SPLICING

Laminated belts is gained from the fact that each and every belt is thoroughly stretched on an unique stretching apparatus, on which every belt is tested out before shipment to the consumers. The belts are so elastic and pliable that a ¾-in. thick Albeco, equal to a 4-ply multilapped belt, is stretched over 14-in. diameter pulleys. The makers claim that with a belt of this type more power can be secured from a given width than would be possible with any other type of construction

BIRD'S BULL'S-EYE BELTING

J. A. & W. Bird & Co., Boston, Mass.

THE BELTING MADE by this firm is constructed of specially woven canvas, folded as many times as the ply requires, and then stitched lengthwise of the belt, the rows of stitching being very close together. This stitching is done at exactly the right tension to allow sufficient pliability yet give the necessary firmness and solidity to prevent any possible separation of the canvas.

This stitched canvas is then run through powerful rolls, which subject it to an intense strain, opening up the fabric and stretching it to the extreme limit. While in this condition a heavy gum compound is forced, by mechanical pressure, into the canvas, filling up the belt and making it one solid body composed, to all intents and purposes, of this gum compound which encases and protects every fibre.

This gum compound itself is composed of ingredients that have been repeatedly distilled to remove all volatile elements and produce in combination a tough flexible material which is unaffected by heat, moisture, alkalies, fumes, acids or gases and is absolutely water and damp proof.

The manufacturers claim that Bird's Bull's-Eye Belting absorbs no moisture and insures the minimum belt contraction and expansion, thus reducing the strain on shafting and effecting a saving of the time usually spent in taking up and piecing belts.

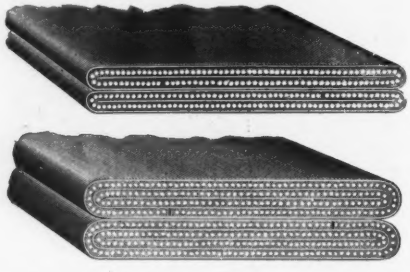
The gum compound filler gives great elasticity to the belt, which can therefore be run slack under a full load, forming a greater arc of contact and transmitting the maximum power.

This requires no dressing. The gum compound always insures a smooth surface to the belt and this surface possesses a strong pulley adhesion which is claimed to prevent absolutely belt slipping and its concurrent waste of power.

RUBBER BELTING

Boston Belting Co., Boston, Mass.

HEAVY COTTON DUCK specially woven, a special compound prepared to give the most adhesion, and a rubber cover with smooth finish make up the constituent parts of the Boston Belting Co.'s product. All its belting is double stretched, and in the Imperial brand the

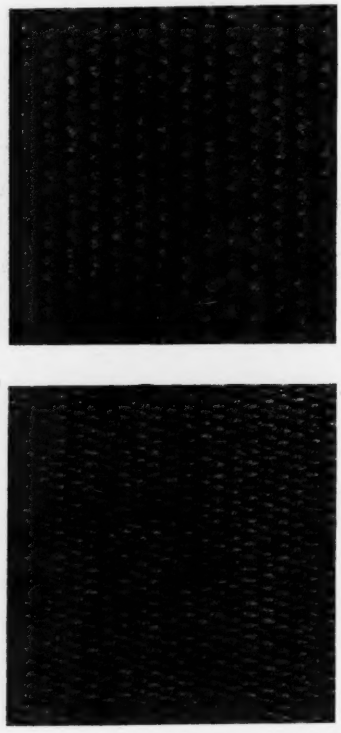


CONSTRUCTION OF THE FORSYTH SEAMLESS RUBBER BELT

plies of duck are stitched lengthwise of the belt with sea island cotton yarn in rows about 1 in. apart before the rubber cover is put on. This brand is especially recommended where the pulleys are small, as the additional strength makes it possible to use one less ply than in regular belting.

Frictioned surface belting is made of either regular weight heavy duck or a fine light duck and in both cases without the ordinary rubber cover. It is known as the Universal brand and the makers especially recommend it for use in connection with planing mill and woodworking machinery or where pulleys are small and run at high speed.

In the manufacture of Eel Skin belting, cotton yarns are used woven under heavy tension and the belting is then impregnated with special compound, making it waterproof and hardening the surface so that it gets a good grip on the pulleys. The Eel Skin belt is woven in a single operation, solid, is absolutely seamless, and has no plies or stitching so that it cannot separate or come apart. The manufacturers state that it is not affected by heat, cold, moisture, dryness, oil, grease, steam or acid fumes and does not become excessively hard through disuse. Because of its great pliability it can be run on smaller pulleys than is usual for belts of a given thick-



EEL SKIN BELTING, COARSE AND FINE WEAVES

ness. Some form of metal fastener is recommended for joining the ends of belts or for extremely small pulleys wire belt lace, the strands of the belt being separated by the use of a belt awl and not punched.

Gutta-Balata belting has as a base a heavy duck, closely woven from hard twisted cotton yarn and treated with a Gutta-Balata compound, then cut and folded to make what appears to be 2 separate belts of the same width. The side of each separate belt having the selvages is next given a special coating and the 2 belts are then united so that the bond between them is not only equal in strength but stronger than that between the plies in other belts. This method of belt manufacture is covered by the Forsyth patent. The Gutta-Balata belting is waterproof and requires no dressing, but if the surface becomes dry or considerably worn a light application of castor oil or boiled linseed oil overcomes the difficulty. When used in a crossed belt the manufacturers recommend a small amount of floated plumbago applied with a cloth.

DEFIANCE BELTING

The Diamond Rubber Co., Akron, O.

THIS IS MADE with long staple cotton in the duck which is the foundation of the belt, and this duck is made with a special frictioned surface of high grade Para rubber. A special process is used so that the rubber thoroughly permeates the duck to prevent mildew and exclude moisture. The stretch is taken out in manufacturing.

Between the plies a distinct layer of rubber is introduced, adding greatly to strength and pliability, the tenacity between plies being shown by the lower illustration.

Other brands of belting made by the same company are Paper Mill, Diamond, and Titan. Defiance brand is made as the manufacturers term it "fool

ROLL OF DEFIANCE BELTING AND ENLARGED SECTION

proof"; Paper Mill is nearly so, while Diamond and Titan are not. Rules given by the Diamond Rubber Co. in regard to the use of its belts are as follows: Large pulleys are always desirable, and it is better to make a pulley and belt wider than increase the number of plies where possible. Five-ply belts should be used on 18-in. diameter or larger, 6-ply on 30-in. pulleys or larger, and 8-ply on 48-in. or larger; the pulley face should be wider than the belt, and the crowning should not exceed ⅛ in. per foot in width. The pull properly carried by belting is for 3-ply, 40 lb. per inch of width; for 4-ply, 50 lb.; for 5-ply, 50 lb.; for 6-ply, 60 lb.; for 7-ply, 70 lb.; for 8-ply, 80 lb.; and for 10-ply, 120 lb.

In cutting belting from the roll, cut it ⅛ in. short per foot to allow for the stretch. Where it is desirable to lag pulleys, rubber frictioned cotton duck is recommended. Whipping of belts is one cause of rapid wearing, and where drives are more than 25 ft. centers heavier ply belts are required than the horsepower would indicate.

RUBBER BELTING

The Gutta Percha & Rubber Mfg. Co., Chicago, Ill.

THIS COMPANY MAKES several brands of rubber belting, among which are the following:

Sagamore brand, made on 32-oz. duck and with a high grade of rubber or friction with friction surface. This belt is specially adapted for hard places, such as paper mills, saw mills, mines, etc. Maltese Cross brand, made on 32-oz. duck, best quality of rubber, with a smooth rubber cover, and is used largely in mining and saw mill work. Montana Sewed brand a high grade belt, made on 32-oz. duck, the plies of which are sewed together, especially for places where sewed belts are required. Red Strip, their leading brand, a belt for universal work, made of the best of material, fully stretched, and designated by a strip of red rubber under the lap. Mohawk brand, made on medium weight duck with a good quality of rubber both in friction and cover. Special Elevator brand, a heavy belt, made on 32-oz. duck, especially made for elevator and conveying purposes.

LEATHER BELTING

New York Leather Belting Co., New York, N. Y.

THIS LEATHER BELTING is manufactured on a quality basis in all its details from the selection of the hides to the finished rolls of belting ready for use. Only Chicago packer hides are used free from grubs and cuts and the long tanning process is used, nothing being forced to gain time at the expense of costs.

The currying is a special and secret process that follows as nearly as possible the natural way of getting the animal oils back into the hide and under the natural conditions that prevailed while the hide was on the steer's back.

Cutting is a process on which great stress is laid in order that an absolute method, instituted by the company, may be followed. The limits of the hide area used are confined to that part of the hide only contained in 4 ft. from the tail to the shoulder and to within 15 in. on either side of the backbone. This insures the customer getting that "centre stock" which is strictly a confined centre stock, the base of the quality and pulling power, along with the long life of this leather belting.

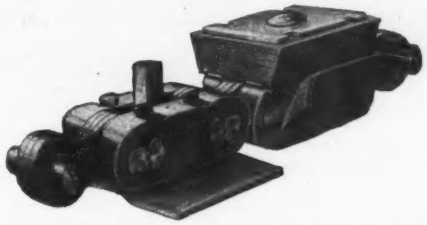
The special grades are Phoenix and Wetite, the latter being waterproof leather belting, also the Imperial brand, a strictly first grade leather belting.

In strictly adhering to the selection of hides that are as nearly perfect as possible to get for high grade belting purposes, the company follows a principle from which it never departs, that is, of making the best leather belting that it possibly can, backed up by long experience necessary and the ability to carry a stock of belting butts that enables it to use nothing but the best portions.

THE PEERLESS V BELT

Peerless V Belt Co., Chicago

THIS BELT is a combination of friction material and steel. As shown in the illustrations, the belt is made up of a bevel steel chain for core, having a sectional strip of Krome tan leather surrounding this



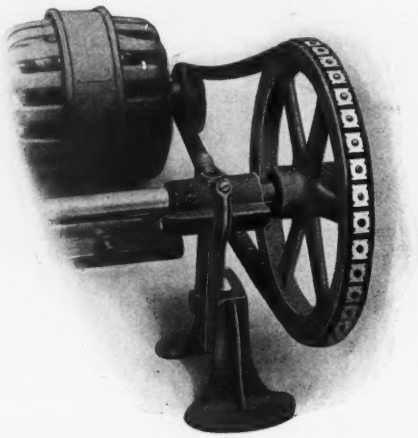
SECTIONAL VIEW OF PEERLESS V BELT SHOWING CONSTRUCTION

chain from below and forming a continuation of a sectional strip of friction board on top, all parts being held firmly together by a rivet passing through the links, as indicated in the sectional view. Chain joints are of the improved frictionless rocker type, making

it possible for the belt to bend around small sheaves without injury or displacement of the bearing point, so that the chain and the friction material have equally long life.

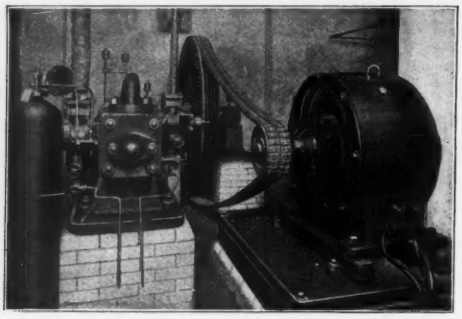
The single chain is shown driving a 2-hp. line shaft at 22-in. centers, 1500 ft. per minute, and the multiple chain is shown on a 35-hp. drive for an ice-machine.

Data for figuring these drives as furnished by the company are as follows: To transmit 1 hp. per strand for a 1¼-in. strand on a 5-in. pulley, use 425 ft. per minute; on a 6-in. pulley, 325 ft.; on an 8-in. pulley, 250 ft.; and on 10-in. and above, 200 ft. For a ⅞-in. strand on a 4-in. sheave, use 1000 ft. a minute: on a 5-in. sheave, 800 ft.; on a 6-in. sheave, 700 ft.; and on 8-in. and over, 600 ft.



SINGLE STRAND DRIVE FROM 2-HP. MOTOR

To get the shortest distance permissible between centers of shafts, for a ratio of 1 to 2 and 1 to 3, the sums of the diameters of the large and small sheaves; the center distance should be not less than 24 in. For a ratio of 1 to 4, 1 to 5 or 1 to 6, the shortest distance on centers is the diameter of the large sheave plus twice that of the small sheave; for a ratio of 1 to 7 or 1 to 8, the large diameter plus 3 times the small; for a ratio of 1 to 9 and 1 to 10, large diameter plus 4 times the small; for a ratio of 1 to 12, 1 to 13 and 1 to 14, the large diameter plus 5 times the small. If closer center distances are required than those given by the foregoing rule, more strands of belt must be used and the horsepower per strand at a given speed decreased because the arc of contact and the weight of belt is less on the sheaves. It would be better to refer such drives to the manufacturers for figuring.



35-HP. MULTISTRAND DRIVE FOR ICE MACHINE

Belt speed of 1400 to 1800 ft. a minute is found economical and desirable, and the limit of belt speed for ordinary purposes is 2000 ft. a minute, although somewhat over this may be used where the sheaves are large and center distances long.

The data as given above do not cover overloads and are for drives operating 10 hours a day. If the service required is 24 hours a day, the drives must be figured heavier in order to be durable. Where more than 1 strand wide is required, steel straps across the top connect the strands into a single belt.

QUAKER CITY BELTING

Quaker City Rubber Co., Philadelphia, Pa.

THE "SAVING-AT-the-spigot-and-losing-at-the-bung" policy of installing the most-approved types of power-generating equipment, and losing the power in transmission, should be a thing of the past in the modern plant.

An important problem, now, is to secure belting that will transmit all the power. Quaker City is a superior belt, constructed on 32-oz. cotton duck, specially woven to stand great strain. The plies are cemented together with good Para rubber friction, and the outside is coated with rubber compounded to withstand the greatest wear. It is especially made for main belt duty, and is practically serviceable for elevator belts, paper mills, dye and print works, and coal breakers. It is guaranteed by the makers for hard service.

LANCO BALATA BELTING

The Republic Rubber Co., Youngstown, O.

ONLY 2 MATERIALS enter into the construction of this belting, cotton duck and Balata gum. The fabric is made from the American long staple cotton, specially selected and woven for the purpose, and the Balata gum is reduced to a liquid condition by a secret impregnation process and applied to the fabric in that condition. So thorough is the impregnation obtained by this process that every strand and fibre of the duck obtains a waterproof insulation of the gum.

In the Lanco process the belting is never subjected to vulcanization by heat, which eliminates the risk of carbonizing the duck.

Lanco belting has a breaking strain of over 9000 lb. per square inch, and 6 in. 4-ply belting will stand a tensile strain of over 5 tons without breaking.

SCHIEREN BELTINGS

Chas. A. Schieren Co., New York, N. Y.

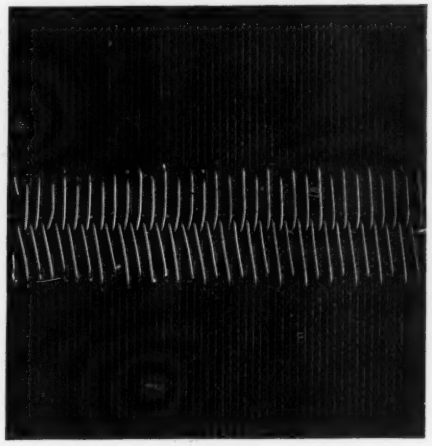
THESE BELTINGS ARE all of the finest quality leather, but selected to fill different requirements. For small pulleys and high speeds the Texas Steer Belting is especially suited. For heavy drives, such as rolling mills and main drives, the Bull's Head is adapted. For general mill work the Royal Extra Belting will fill the requirements and for places where waterproof and steam-proof belting are needed, the Duxbak in one or the other type is desirable.

The Duxbak waterproof is for use in wet places where the temperature does not exceed 140 deg. F. Steamproof Duxbak is for use in live steam and in places where moisture is accompanied with extreme heat, also where the belt is exposed to acid fumes or strong alkalies. The company makes also patent joined leather link belting.

VICTOR-BALATA BELTING

Victor-Balata and Textile Belting Co., Easton, Pa.

VICTOR-BALATA is made of specially woven and extra heavy duck of 37 oz. weight. Balata gum, a South American product, is forced into the fibres of the duck until they are thoroughly impregnated, thus forming an absolutely waterproof combination.



JACKSON WIRE LACING

This gum does not simply form a surface layer or coating, but it is a part of the belting base itself, and as this gum is of a tough nature and possesses great strength, Victor-Balata belting will stand a tensile stress of nearly 9,000 lb. to the square inch. Balata gum is a natural preservative, not affected by general climatic conditions, therefore the natural life of this belting is indefinitely prolonged as the belting is impervious to the action of water, dampness, grit and dirt, certain oils, etc., that are injurious to ordinary textile belts.

It is claimed that by reason of the great flexibility of this belting, it is specially adapted for hard drives having turns such as those involving the use of mule pulleys. A peculiar inherent quality in the Balata gum is its clinging tendency so that Victor-Balata belting clings to the surface of the pulleys without the use of belt dressings.

As there are no seams nor joints in Victor-Balata belting, it pulls straight and even, runs true on the pulleys, and has practically no stretch, so that once installed, there is little necessity of taking up the belt.

Victor-Balata belting can be made endless with no difficulty and with the absolute assurance that the joint will be as strong if not stronger than the balance of the belt itself. When not required to be endless, there are several effective joint schemes, besides lacing, in the shape of wire joints and other forms, each one especially fitted to suit the case and dependent also upon the size of pulley.

Some of these are shown elsewhere in this issue of the Practical Engineer.

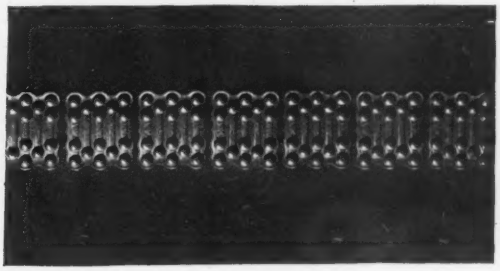
CLING-SURFACE

The Cling-Surface Co., Buffalo, N. Y.

THE OBJECT IN VIEW in the preparation of Cling-Surface is to supply a neutral treatment preservative in every sense, which will make and keep the belt in vigorous health, pliable and waterproof, and prevent drying or cracking so that the belt can work and last. Then to make it work by stopping the slipping better than tension can stop it, so that belts can run easy or slack and carry their loads.

The possibility of so running belts is of great value, as it means ease on the belts, bearings, shafting and engine; cool bearings, greater economy of oil and a reduction in the friction load of the plant, while the larger wrap on pulleys increases the transmitting capacity of the belt.

Cling-Surface may be used for leather, cotton or camel hair belts or manila rope, into all of which it



JOINT WITH CRESCENT FASTENER

penetrates, while for good rubber or balata belts in light applications it refreshes the surface rubber, and in old belts waterproofs any canvas exposed from the

EFFECT OF APPLICATION OF CLING SURFACE RUBBER BELTING

absence of the rubber. Some of the results are shown in the illustrations herewith and on pp. 12 and 13.

STEPHENSON BAR BELT DRESSING

Stephenson Mfg. Co., Albany, N. Y.

THIS COMPANY HAS specialized in belt dressing since 1888 and now makes 4 kinds, Red Label for use on leather belts, Green Label for use on rubber, canvas and

balata belts, Brown Label for use on rope drives, and Black Label for use on chain drives. All 4 forms are made up in the round bar ready for convenient use.

NEPTUNE WATER PROOF LEATHER BELTING

Graton & Knight Mfg. Co., Worcester, Mass.

THIS IS AN OAK tanned leather belting prepared especially for use in damp places or where it is in contact with steam. The manufacturers state that Neptune water proof belting can be soaked in water indefinitely and the lap will not separate, nor will the double belts come apart in the plies. The makers also guarantee that the Neptune can be run out of doors if necessary in all sorts of weather and will stand up to the work.

SAWYER STITCHED BELTING

The Sawyer Belting Co., Cleveland, O.

CAREFUL CHOICE OF long fiber material and a process of manufacture to give the greatest strength combined with flexibility give this belting its enduring qualities.

It is made of a special constructed close woven duck, a special width being made for each width of belt, giving 2 selvage edges. It is folded by special machines and stitched with a high-test cord in rows ¼ in. apart, each row being perfectly straight the entire length of the belt, preventing any possible separation of the plies and insuring a smooth even surface. The improved method of dressing is claimed to render the Sawyer belts proof against water, steam, oil or gases, heat or cold.

ORIGINAL GANDY BELTING

The Gandy Belting Co., Baltimore, Md.

THIS STITCHED BELTING is the result of 20 years' experience and is made from a fine grained, specially woven duck woven for each width of belt. It is sewed under tension from end to end, and is waterproofed by a special process.

By an original treatment, all parting or splitting of ends is obviated, hence no air puffs can form. It is thoroughly stretched and seasoned, is uniform in surface and is not affected by atmospheric changes or acid fumes. The stitching gives firmness and strength necessary for great durability, yet leaves it flexible so that it clings well to the pulley and thereby secures increased tractive power.

PEERLESS BELTINGS

The Peerless Rubber Mfg. Co., New York, N. Y.

RAINBOW BELT WHICH was first introduced in 1895 is especially strong and flexible, being made from extra heavy duck woven from the finest Texas pickings. Each belt is stretched on a patent stretcher, and has a guaranteed friction test of 22 lb. It is especially adapted for high speed work and on small pulleys or for extra hard work.

Other brands made by the Peerless Company are the Fortune, the Peerless, and the Durham which are of good grades, but not as high quality as the Rainbow. To meet the demand of certain paper and saw mills, elevators and so forth, a stitched Peerless belting is made, in which the plies are joined by Para rubber friction as well as by the stitching.

For special work the Fortune and Peerless brands are made up with a frictioned surface, this belting being made on a lighter weight duck than ordinary rubber belting and requiring therefore a greater number of plies for a given horsepower.

As a rule for figuring the horsepower of rubber belting the Peerless Company gives that a 4-ply rubber belt running 4000 ft. a minute will transmit 5 hp. per inch of width. The power is proportionate for other plies and speeds. Another simple formula proposed is: Multiply the number of plies in the belt by the width of the belt in inches, by the diameter of the pulley in inches, and by the revolutions per minute of the pulley, and divide by 12,000. The answer will be the horsepower of the belt.

For the western territory, these brands of belting are all handled by the Geo. B. Carpenter Co., of Chicago, Ill.

PLOMO BELT DRESSING

Plomo Specialty Mfg. Co., Cleveland, O.

THIS DRESSING IS designed to prevent slipping, and to keep the belt in its original condition, by retaining the lubrication put in by the belt manufacturer. After several applications, when properly applied, it forms a tissue coating on the surface of the belt, and this prevents the evaporation of the lubricant put into the belt when it is made. The manufacturers state that belts of which the back and edges are painted annually with Plomo dressing become waterproof and weatherproof and will retain their pliability and elasticity when exposed to water, steam or steam heat. Plomo belt dressing requires no heating, can be used with satisfaction on all kinds of belting; a very small quantity being sufficient for an application.

GOODRICH BELTING

The B. F. Goodrich Co., Akron, O.

THIS COMPANY MAKES the Pinnacle brand, frictioned surface style, of quality for severe service; advisable for general driving purposes, on main drives or other service where the conditions are severe. Titanic brand, regular covered style, intended for main drives or other places of severe usage. Pilgrim brand, regular covered style, of good strength and durable quality for all general drive purposes, and used frequently for main drives under favorable conditions. Rob Roy brand, regular covered style, reliable quality for ordinary drives. Marathon brand, friction surface style, of special construction for high-speed small-pulley machines.

TO FIND THE LENGTH of belts when a tape cannot conventiently be used: For open belts, if both pulleys are nearly the same size, add the diameters of the 2 pulleys together, multiply this sum by 1.5708. To this product add twice the distance between centers of the shafts.

If one pulley is considerably larger than the other, square the distance between centers of shafts, add to this the square of the difference between the radii of the 2 pulleys and extract the square root of this total. Multiply this root by 2; next add the diameters of the 2 pulleys and multiply by 1.5708 and add this product to the product previously found; the sum will be the total length of the belt required.

For crossed belts; square the diameter of the larger pulley and the distance between centers and add these squares; extract the square root of the sum. Next square the diameter of the small pulley and the distance between centers, add these squares and extract the square root of the sum. Add the 2 roots thus found, also half the circumference of each pulley, and the total will be the required length.

PULLEYS

IN the installation of any system of mechanical power transmission, vital points to be considered are the pulley arrangement, size and material. There are many points which may be brought out and enlarged upon in order to show the saving and economy of certain classes of pulleys in preference to others for the particular work at hand. Numerous experiments have been performed with the various materials, types and shapes of pulleys and their value for different installations has been quite thoroughly worked out.

Materials

IN the construction of pulleys the materials now common are cast iron, steel, cast iron with steel rim, wood, cast iron with wood rim, and paper.

The most common pulley now employed is made of cast iron. It presents the advantage that it is easily

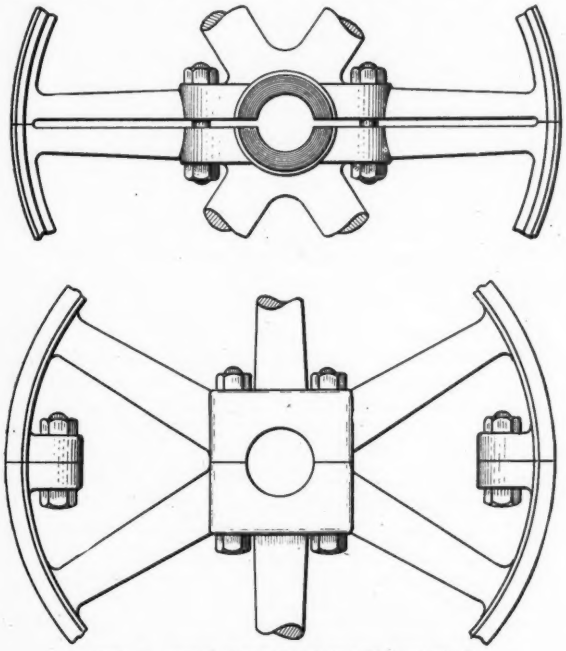


FIG. 1. TWO FORMS OF SPLIT PULLEYS

made, its belt friction is high, it is strong and its strength can be calculated with a certainty, the speed limit is high, balancing is easily done and the pulley is practically moisture proof. On the other hand the pulley may easily be broken by a shock or blow, and when so broken is not easily repaired. It is somewhat heavier than steel, wood or paper for the same service, the cost is high compared with wood or paper pulleys, and it is subject to internal strains due to temperature changes and improper casting.

Steel pulleys are made of either cast or forged steel in either split or solid form. The coefficient of friction is practically the same as for cast iron, but the weight and wind friction are reduced considerably from cast iron and the strength considerably greater as is also the speed limit.

Pulleys with cast-iron hubs and arms with steel rims have become quite popular where high speed is a requisite. The points which recommend them for use are the strength, the light weight compared with cast iron for similar service, repairs to the rim are easily made, and, like the cast-iron pulley, they are not affected by moisture of the atmosphere. On the other hand the cost of these pulleys is high, and the pulley is subject to strains due to temperature changes.

Split wood pulleys are becoming continually more popular owing to their low cost, absence of strain due to temperature, to their ability to withstand shocks and jars without breaking, their comparatively light weight, and the fact that they can be mounted upon shafts without keys or set screws. These pulleys, however, are seriously affected where moisture is present, the life of the pulley is not so long as that of the cast-iron or steel pulley, nor is the strength of the pulley so great as that made of metal.

Paper and pulp pulleys are more recent developments and combine strength and durability with a high coefficient of friction.

In comparing the strength of pulleys the results of tests made at Purdue University are of interest, showing the bursting speed of several kinds of pulleys. Two tests on solid wood pulleys gave 285 and 267 ft. per second as the bursting speed. Split wood pulleys withstood speeds of 232 and 221 ft. per second. The

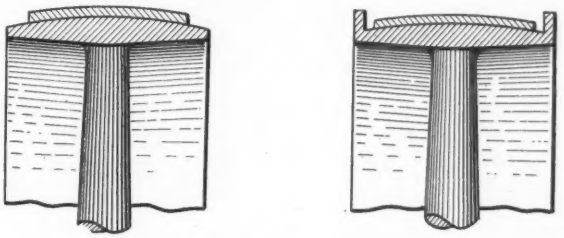


FIG. 2. RIMS OF CROWNED AND FLANGED PULLEYS

results recorded for bursting speeds on paper pulleys were 295 and 307 ft. per second. Two split steel pulleys gave way at 235 ft. per second.

Tests made at Sibley College, Cornell University, resulted in the following maximum horsepowers per square inch of belt cross section of belt, which were developed at 3500 ft. per minute; when the tension on the tight plus one-half the tension on the slack side equaled 180 lb.; on a pulp pulley 5.4 hp. was developed, a wood pulley gave 5.5 hp. maximum, cast iron 8.5 hp., and paper 10.7 hp. When the tension on the tight side plus half the tension on the slack side equaled 300 lb. the results were as follows: Pulp 10.2, wood 10.4, cast iron 16.7, paper 21.6 hp. These maximum values occurred at about 4500 ft. per minute speed of belt. Other tests at different belt tension showed about the same ratio.

Forms and Proportions

THE class of work to be performed by a pulley determines largely the form and proportion which the pulley should have. A solid pulley is suitable for installing upon the end of a shaft where it can easily be reached and taken off without interfering in any way with the alinement of the shaft or other machinery in the plant. These pulleys are set with keys or set screws, keys being used where the load to be

transmitted is heavy and set screws only where the load is very light, set screws being spotted into the shaft.

When it is desired to place a pulley at the center of a shaft, a split pulley is most convenient, as it can be mounted without taking down the shaft and other pulleys placed upon it. These pulleys are generally made in 2 parts and may be set upon the shaft either with a key, set screw, or entirely by friction, the latter being preferable in all cases where it is possible, as no injury to the shaft is then necessary. Either the solid or split pulley may be made of nearly any material now used for pulleys, and the choice is largely a matter of opinion with the engineer in charge.

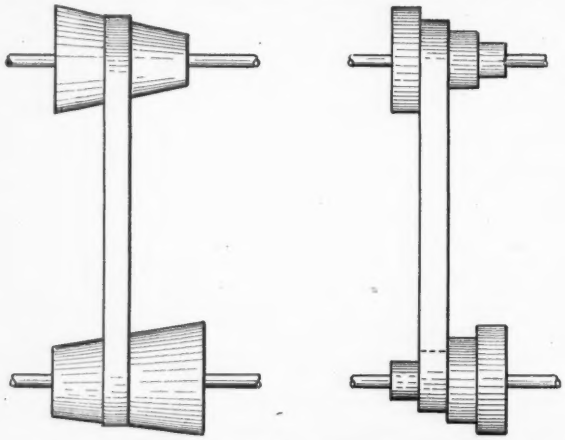


FIG. 3. CONE AND STEP PULLEYS

The type of rim adopted depends entirely upon the character of the work which the pulley is desired to do. The flat face, that is, where the face of the pulley is straight and parallel with the shaft, is commonly employed where a belt must frequently be shifted from one pulley to another, but for isolated work it is desirable to use a crowned pulley which keeps the belt at the center of its face, thus reducing the danger of the belt running off.

For certain classes of work where the pulley is subject to considerable shock or jarring the rim is

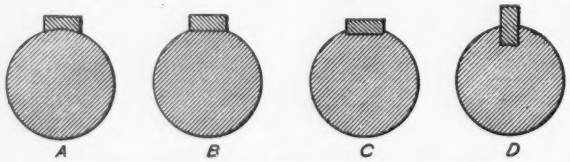


FIG. 4. FORMS OF KEYS USED FOR PULLEYS

flanged, thus keeping the belt from running over the edge. In some installations it is desirable that a small variation in speed is made possible during the running of a belt. In these cases a cone speed pulley is employed which consists of 2 cones of equal and similar dimensions, but sloping in opposite directions. A modification of this drive is the step pulley which permits a variation in speed from the line shaft to the machine operated, but these speeds are constant and cannot be changed during the operation of the machine.

The rims of pulleys are frequently perforated, which, it is claimed, increases the friction between the belt and the pulley by letting out the film of air, thus giving more efficient operation of the belt.

The arms of metal pulleys are either round or elliptical in cross section and usually extend radially from the hub, but they may be curved or double curved which makes the pulley more elastic. Frequently in small pulleys no arms are used, the pulley being made with a solid web in the place of arms. Split wood pulleys have various forms of arms, but the most common have parallel arms on either side of the dividing line, with the addition of radiating arms when the size demands a more solid pulley.

In order to secure the best operation of a belt drive the diameter of the pulley should be equal to or greater than 36 times the belt thickness, but in the case of link belts 30 times the thickness of the belt. The ratio between the driving and driven pulleys should not be greater than 6 to 1 and the distance between them depends upon the ratio of the diameter, thus where the ratio is 2 to 1 the distance should be greater than 8 in., 3 to 1, 10 in., 4 to 1, 12 in., 5 to 1, 15 in.

For best operation the convexity of a crowned pulley should be 1/20 the width of the belt and for all pulleys the width should be equal to 5/4 the width

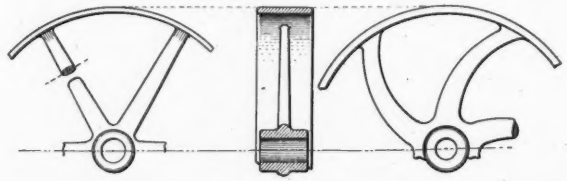


FIG. 5. STRAIGHT AND SINGLE-CURVED PULLEY ARMS

of the belt where an isolated pulley is employed. This may be made smaller where the belt is shifted from one to another running beside it.

The thickness at the edge of the rim for iron pulleys is usually taken at 0.01 the face width plus 0.08 in. The thickness of the rim at the center is equal to twice that at the edge, plus the amount of convexity. The rule taken for the thickness of the nave or hub is that this should be 0.4 in. plus 1/6 the diameter of the shaft, plus 1/50 the radius of the pulley, the dimensions all being in inches. The length of the nave should be equal to or greater than 2.5 times its thickness.

Keys employed for fastening pulleys to the shaft are of 4 kinds, the hollow key as shown at A in Fig. 4, is used for light work and depends entirely upon friction to hold the pulley from turning. The flat key as shown at B in Fig. 4, is used for medium service and requires that the shaft be marred if this key is employed. For heavy work a counter sunk key is employed, this also requires that a key seat be made in the shaft. Feather keys are used where the pulley must be shifted along the shaft. The proportions of keys of different types are given in the article on shafting in another part of this issue.

Arms

IN iron pulleys the oval shaped arm is most common, dimensions of the cross section being, for the large diameter twice that of the small diameter, the large diameter being in the plane of the pulley. These arms may be either radial, curved or double curved. The rule for the number of arms employed is: Divide the radius of the pulley by the width of belt, to the quotient add 5, then divide by 2, the result will be the number of arms. The long diameter of the

cross section of the arm is equal to 0.24, plus 1/4 the width of the belt, plus the radius of the pulley divided by 10 times the number of arms; this being the diameter of the nave, the small diameter is one-half this amount. At the rim the dimensions of the arm are taken equal to 2/3 the dimensions at the nave. These proportions are admirably adapted for large pulleys, but in smaller ones they should be increased in order to take care of slight defects in castings.

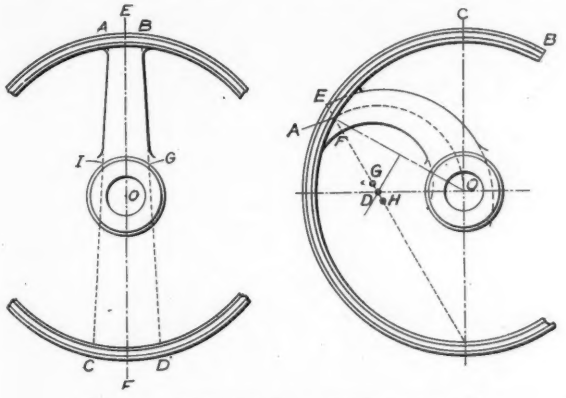


FIG. 6. METHODS OF LAYING OUT ARMS

To lay out the profile of a straight arm, having determined the diameter of the pulley and the dimensions of the arm and nave, draw circles to scale representing the rim, nave and bore of the pulley, as shown in Fig. 6. Draw the diameter EF through the center O. Lay off FD, FC and AB equal to 2/3 the large diameter of the arm cross section at the nave. Draw the lines AC, BD, the parts AI and BG being the profile of one arm. The other arms are laid out in the same manner and equal to this one.

The manner of laying out a curved arm is somewhat more complicated. With a radius OA equal to the radius of the pulley scribe an arc which covers an angle of about 120 deg. On this arc lay off AC equal to 2/3 the arc between arms of the pulley. Then draw the radial line OC and perpendicular to it at O draw the line OD. From the center of the

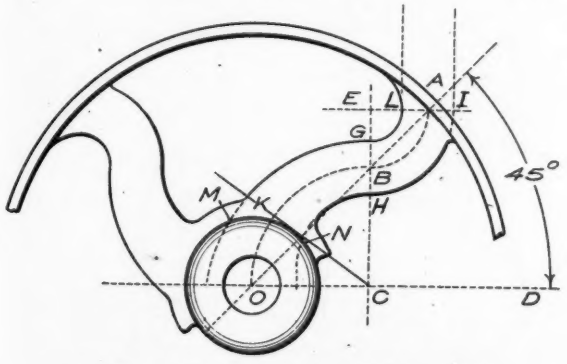


FIG. 7. LAYING OUT A DOUBLE CURVED ARM

line OA erect a perpendicular ED which intersects the line OD at D. From D as a center with DO as a radius scribe an arc AO which is the axis of the curved pulley arm. Locate E and F on the line AD, each at a distance equal to 1/3 the large diameter of the cross section of the arm from A, locate G and H on the line AD, each at a distance from D equal to half AE, now with H as a center and HE as radius, draw another arc extending from the rim of the wheel to the nave. This is the outer profile of the arm and for the inner profile use the center G with the radius GF, and draw an arc from the rim to the nave of the wheel.

One method of laying out a profile of a double curved arm is as follows: Having drawn arcs to represent the nave and rim of the pulley, draw the radial line OA at 45 deg. from the line OD, Fig. 7.

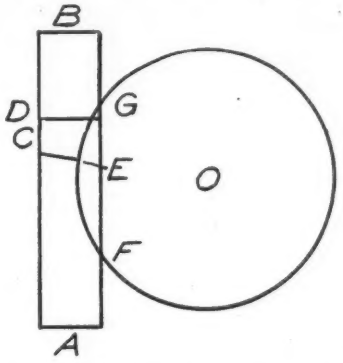


FIG. 8. TEMPLET USED IN LAGGING PULLEYS

Take the point B, on OA at 2/3 the distance OA from O. Through B draw the line EC perpendicular to OD, then draw AE parallel to OD. The points E and C are the centers from which the axis of the arm is drawn. From E as a center and EA as a radius scribe an arc AB and from C as a center and CB as a

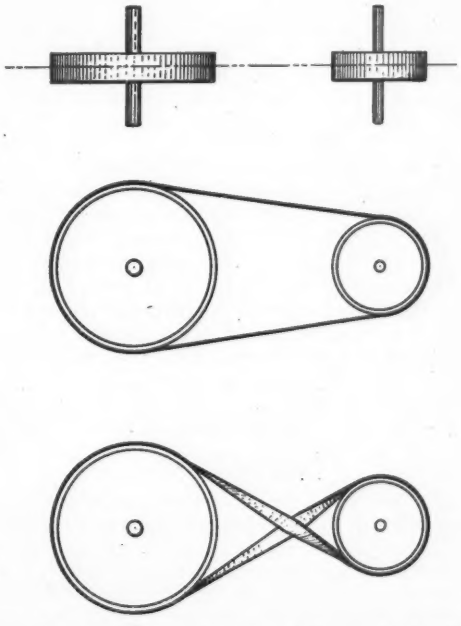


FIG. 9. OPEN AND CROSSED BELT ARRANGEMENT

radius scribe an arc BK. The line thus formed is the axis of the double curved arm. On the line EA extended, take AI equal to 1/3 the large diameter of the arm at the nave and AL of the same length, then from E as a center and EI and EL as radii, scribe arcs IH and LG respectively. Having laid out the large diameter of the arm upon the nave, find centers

upon the line BC from which arcs may be drawn from G and H to the points upon the nave. This gives the profile of one double curved arm and the rest of the arms are made similar to it.

To design a set of cone or step pulleys which will maintain an equal tension of the belt at all speeds of

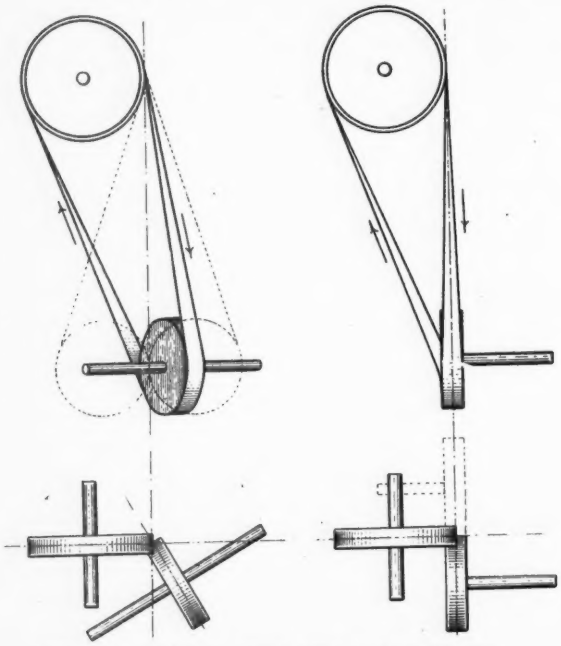


FIG. 10. QUARTER TURN BELT ARRANGEMENT

the drive, 2 equal and similar cones tapering in opposite ways are selected as the line of centers for the pulleys when crossed belts are employed. There are, however, few cases where it is advisable to use crossed belts for cone pulleys, owing to the severe wear upon the belts, and to design a set of pulleys for open belts, 2 similar conoids tapering in opposite directions and bulging in the middle are employed. The line representing the centers of the various steps is laid out according to the following rule, given by Rankine: The radius of the center pulley is equal to 1/2 the sum of the radii of the large and small pulleys of the cone, plus the square of the difference between the large and small radii of the cone divided by 6.28 times the distance between the axis of the cones. While this does not give an exact solution it is sufficient for all practical purposes, and an exact result requires the use of higher mathematics.

Lagging Pulleys

IT sometimes becomes necessary to increase or decrease the speed of a line shaft, owing to changes in the power plant. Under these conditions it would be necessary to secure new pulleys of different diameters, or change the diameters of those pulleys employed under the old conditions. The latter method is quite readily accomplished by lagging the line pulleys when the speed of the line shaft is decreased or lagging the driven pulleys in case the speed is increased.

Pulleys made of any material may be lagged with wood, increasing the diameter even as great as 4 or 6 in. To do this, holes are bored into the face of the pulley into which screws are set to fasten the lagging firmly to the pulley. A templet for cutting the lagging is made as follows: With a center O, Fig. 8, and a radius equal to the radius of the pulley to be lagged, scribe an arc. On the edge of this arc, overlapping it 2½ or 3 in., tack a thin piece of board AB,

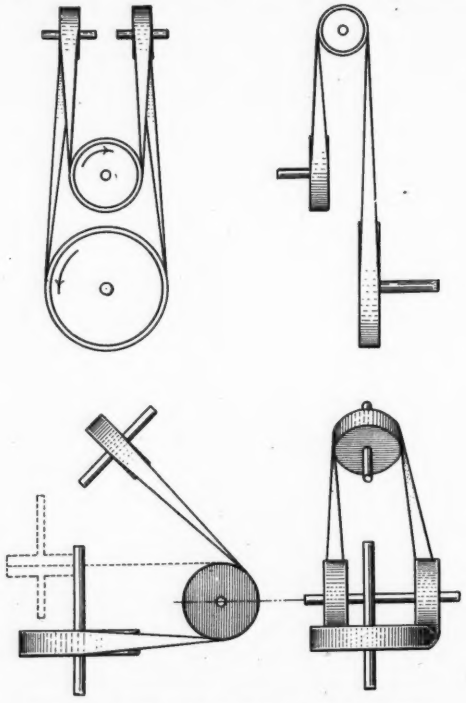


FIG. 11. COMMON USE OF GUIDE PULLEY

then draw a radial line, EC, and the arc EF on this board. With a band or hack saw cut this board along the line FEC. The board may be cut off at DG in order to make it easily handled. With this templet the boards used in lagging the pulley, are laid out and sawed accordingly. The lagging should be placed with the grain running around the pulley and glued

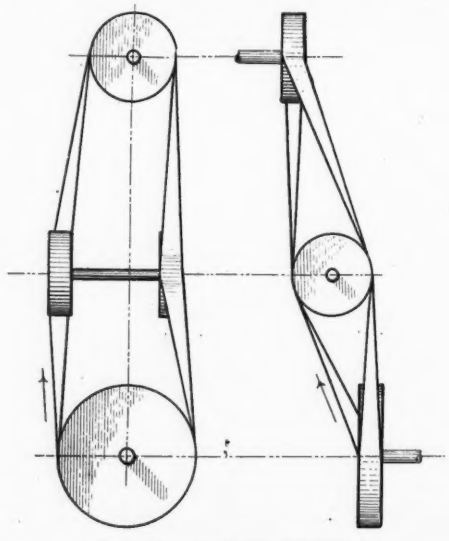


FIG. 12. PULLEYS OFFSET

firmly together when placed in position then fastened with screws. The face should then be turned, and finished by giving it a coat of shellac or varnish.

One of the best methods of lagging a pulley where it is not necessary to increase the diameter a great amount is by means of leather riveted to the rim. In this manner the diameter can be increased to the extent of an inch.

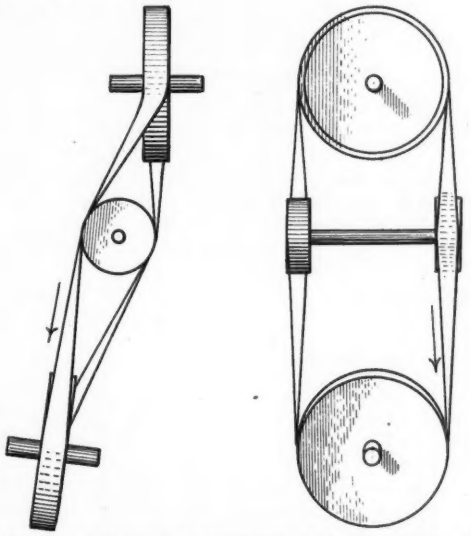


FIG. 13. TRANSMISSION BETWEEN SHAFTS AT AN ANGLE

A rather crude method sometimes employed is to use rope wrapped upon the face of the pulley, but it can hardly be recommended for a permanent job.

Setting Pulleys for Special Transmission

AS a general law for handling all cases of pulley setting in belt transmission it may be stated that the direction in which the belt leaves a pulley must be tangent to the center line of the pulley to which

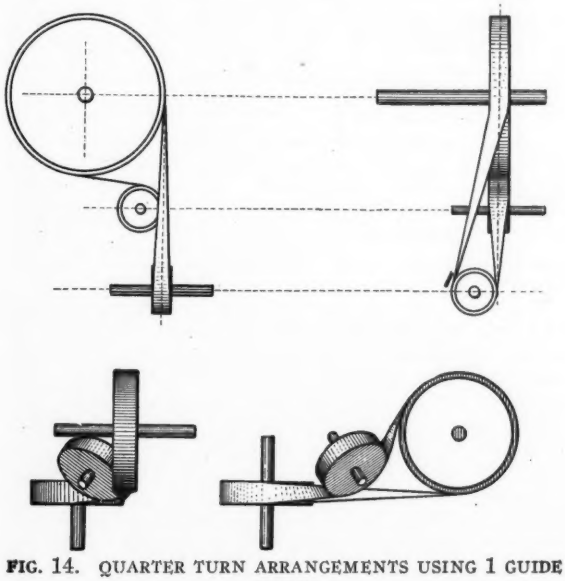


FIG. 14. QUARTER TURN ARRANGEMENTS USING 1 GUIDE PULLEY

the belt goes. Keeping this in mind the following solutions of belt transmission are readily apparent.

Where it is desired to transmit power between 2 parallel shafts the direction of motion being the same, an open belt is used as shown in illustration Fig. 9. This is the simplest form of belt drive and that most commonly employed.

To secure opposite direction of rotation of 2 parallel shafts it is necessary to cross the belt, this arrangement also being shown in Fig. 9. In both these cases the pulleys are placed in the same plane and any ratio of speed up to 1 to 6 may be obtained.

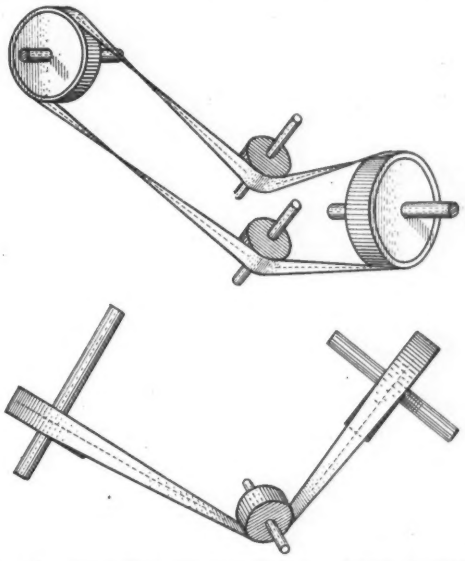


FIG. 15. QUARTER TURN SOLUTION USING 2 GUIDE PULLEYS

When it is desired to transmit power from one shaft to another not in the same plane a quarter turn arrangement is resorted to. The general solution of this problem is shown in Fig. 10, where variation in the angles of the 2 shafts is illustrated.

Use of Guide Pulleys

THERE is no essential difference between a guide pulley and one used for transmitting power, except that its strength need not be so great and that it runs loosely upon the shaft. Guide pulleys are used to direct a belt to the proper place on the main pulleys in drives that are so complicated that direct means will not suffice. Illustrations of their varied uses are shown in Figs. 11 to 16. The arrangement of 2 shafts so close together that a direct belt cannot

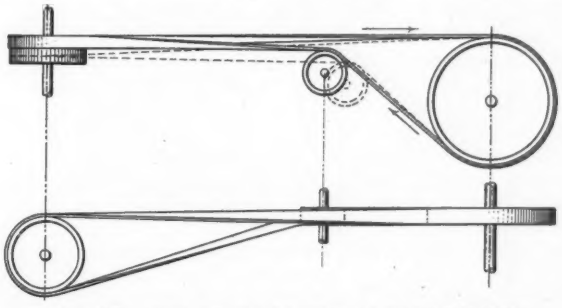


FIG. 16. GUIDE PULLEY USED AS BELT SHIFTER

be used is shown in Fig. 11 where it is necessary to employ 2 guide pulleys which are placed upon the same arbor or may be separated with axes at an angle with each other.

It sometimes occurs that pulleys cannot be placed in the same plane upon parallel shafts, but must be

offset as shown in Fig. 12, and in this case guide pulleys must be employed, these being placed upon the same arbor and run in the same direction, the diameter of the guide pulley in this case being equal to the offset of the main pulleys.

The arrangement of 2 shafts in the same plane but at an angle with each other is shown in Fig. 13. In this case also, 2 guide pulleys are necessary to secure best operation of the belts. A solution of the quarter turn arrangement is that shown in Fig. 14, where one guide pulley is used. The quarter turn arrangement is frequently bothersome and the use of a guide pulley is advisable in a great many cases. Another solution of the same problem is shown in Fig. 15, where 2 guide pulleys are employed.

It frequently occurs that by use of a guide pulley which is adjustable in its position, the belt can be shifted from the loose to the tight pulley as shown in Fig. 16, without the use of a belt shifter.

Belt Tighteners

TO secure the best operation and highest economy from belts it is essential that a constant, uniform tension be employed while the belt is running. Owing to the stretch and shrinkage of belts due to long use or changing conditions of the atmosphere, it frequently becomes necessary to employ some means of taking up the slack which is thus caused. This is particularly the case where belts run between line shafts, or between the engine shaft and a line shaft. It is seldom necessary to employ a belt tightener between the line shaft and a motor or other small apparatus inasmuch as these pieces of machinery are usually provided with means for shifting the entire machine upon its bed, thus taking up any slack or relieving an undue tension upon the belts.

As a general rule the belt tightener consists of a loose belt pulley running upon a shaft parallel to the shaft upon which the succeeding pulley is placed. This pulley is arranged so that it can be shifted at right angles to its shaft and held in any desired position, either by springs, weights or crews, according to the size and power transmitted by the belt.

For small belts the tightener is usually placed upon an arm and presses against the loose side of the belt a short distance from the smaller pulley, thus giving the pulley the advantage of a longer arc of contact with the belt. In this case the tightener is usually held in position by a weight or spring of proper size, thus keeping the belt at the proper tension automatically.

For heavy duty, a large belt tightener is employed, and the tension is regulated by means of a hand wheel and screw, thus making it possible to obtain any desired belt tension. In many cases of this kind the belt tightener is employed for no other purpose than to give greater arc of belt contact on the pulleys.

Another use for belt tighteners is on vertical belts where by increasing the tension the upper shaft is put into service and by decreasing it the belt will hang loose around the driving wheel, thus stopping the upper shaft. This use, however, is not recommended as good practice, for the reason that the driven shaft cannot be stopped instantly, and the belt hanging loose upon the driving pulley is subject to considerable wear at the point where it happens to come in contact with the wheel, and is liable to cause accidents by slipping to one side of the driver and catching on a key or set screw.

In design, belt tightener pulleys are similar to other belt pulleys, but where they run loose upon a shaft the hub is lined with bearing metal or otherwise highly polished. The pulley is also provided with some kind of lubricating arrangement, and should be kept thoroughly lubricated if expected to operate to best advantage.

Fast and Loose Pulleys

IT is only in a few cases that several pieces of machinery operated from the same line shaft are all working at the same time, and in order to stop one machine while the others are still working it is necessary to provide some means by which the driving belt may be stopped without stopping the line shaft.

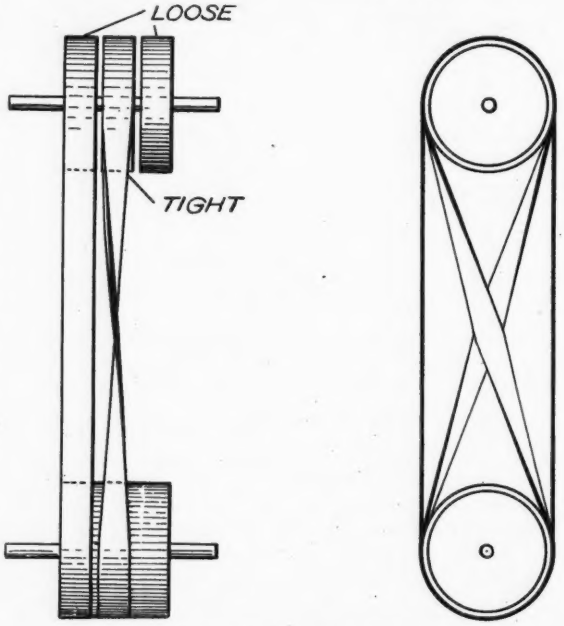


FIG. 17. BELT ARRANGEMENT FOR REVERSING

One of the most common and satisfactory means is to provide a fast and a loose pulley upon the line shaft for each piece of apparatus, so that when a machine is to be operated the belt is shifted to the fast pulley and when it is desired to stop the machine the belt is shifted back to the loose pulley, which is placed upon the shaft directly beside the tight or driving pulley.

The follower or pulley upon the machine is of double width, thus allowing the belt to run from one side to the other as the machine is working or idle. Aside from the fact that the driven pulley is of double width for the belt and has a flat face, its design is usually similar to standard pulleys. The driving pulley and the loose pulley placed upon the line shaft beside it, are of standard design, except the width of the pulley face is not so great as that of an isolated pulley, thus making it easily shifted from one to the other. It is always best where possible to place the tight and loose pulleys upon the line shaft and the double width pulley upon the machine, by this arrangement, when the machine is not in operation the belt is not running, and its life will therefore be lengthened considerably. It frequently occurs, however, that the machine requires considerable power to start it and it would be a difficult matter to shift the belt from one side of the pulley to the other without

having it in motion. In such cases it is necessary to place the tight and loose pulleys upon the machine itself, and the belt must therefore be in operation all the time.

Another arrangement frequently resorted to is that of reversing a machine by means of shifting belts. In this case, however, it is necessary to employ 2 belts, one of which is open and the other

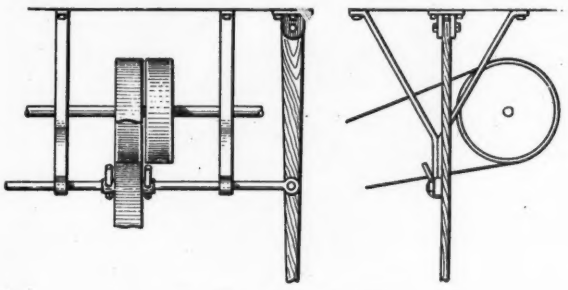


FIG. 18. BELT SHIFTER

crossed. The arrangement also requires the employment of 1 tight and 2 loose pulleys, thus having the loose pulleys on the outside with the tight pulley at the center, the follower pulley having a width a little more than 3 times the width of the belt. Where a machine is periodically reversed an automatic belt shifting arrangement is employed, thus relieving the operator of this responsibility.

Tight and loose pulleys are also frequently employed where a quick return movement of the machine, such as a planer, is desired, by providing 2

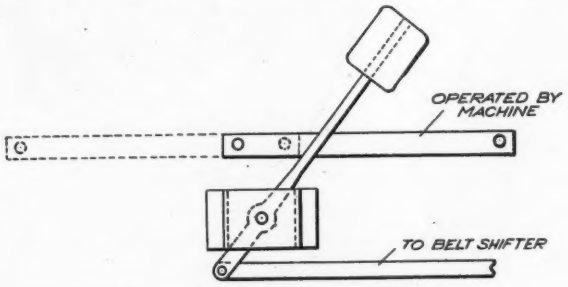


FIG. 19. AUTOMATIC BELT SHIFTING DEVICE

sets of tight and loose pulleys and belts, the ratios between driver and follower being chosen to give the desired speed of the machine.

Belt Shifters

THE most common form of belt shifter consists of 2 parallel fingers placed one on either side of the belt with the space between a fraction of an inch greater than the width of the belt, these fingers being attached to a rod parallel to the shaft upon which the following pulley is placed. This rod is movable endwise the distance the belt has to be shifted and is always placed on the advancing side near the set of tight and loose pulleys. The shifter is operated by a lever or system of levers most convenient to the operator.

As stated above the shifters may be worked automatically, where the machine is to be run alternately in opposite directions, or for a quick return motion which takes place periodically. This is usually done by means of a lever and weight upon the machine, which is operated by the machine until it gets into a vertical position when it drops over to the other side, thus shifting the belt while the machine is coming to rest and starting up in the opposite direction.

Location of Pulleys

TO secure the best service from the belt and pulleys and take advantage of the slack in the belt to give a greater arc of contact on the pulleys, they should be placed with their shafts parallel and in the same horizontal plane and the tight side of the belt at the bottom. This, however, is not always possible, and it is found necessary to run the belt at an angle from the horizontal, but vertical belts should never be employed where it is possible to run them otherwise. The difficulty here is that the belt must always have a belt tightener upon it, as any slack which shows up in the belt causes the lower pulley to slip in the belt. To the difficulty arising from high tension of vertical belts may be added the trouble with an over pressure on the upper shaft bearings and the lifting of the lower shaft in such a way as to wear on the upper part of the bearings. These conditions are unnatural and should be avoided whenever possible.

A driven pulley located upon a long line shaft which has placed upon it several driving pulleys should be located as near to the center of the load as possible. In this way it will be seen that the diameter of the shaft can be reduced considerably, as only half the power of the whole shaft is transmitted in each direction, and also the vibration, which is likely to occur in long shafts.

AMERICAN WROUGHT STEEL SPLIT PULLEY

American Pulley Co., Philadelphia, Pa.

THE MECHANICAL CONSTRUCTION of the American steel pulley admits of a light rim of 1-ply made strong by flanges to which the arms are attached, and by heavy roll beads at the edges of the face. The arms are flat with their narrow edges cutting the air and they converge from near the extremities of the hub on the central flange of the rim so as to make an A

FIG. 1. AMERICAN STEEL SPLIT PULLEY

frame of exceptional strength. On the larger sizes of pulleys, the arms are strengthened at the bend near the hub shell by being thickened at that point. These flat arms are corrugated to give them stiffness.

Owing to the strength of the material used in these pulleys and their light construction throughout, the weight compared with cast iron for the same service

is exceedingly light. This is, of course, an advantage in a great many ways, particularly in the saving of power needed to overcome the friction of bearings upon line shafting. From tests made by the manufacturer, the pulley can be recommended for a peripheral speed of 130 ft. a second.

As is the case with nearly all split pulleys, these are readily applicable to a shaft without taking the

FIG. 2. BUSHINGS FOR AMERICAN PULLEYS

shafting down and they are used with interchangeable bushings, enabling them to be applied to shafts of different dimensions. No key seats or set screws are needed to hold them upon the shafting, since the hub clamps are made of steel of such construction that they grip the shafting closely with enough bearing to prevent the pulley from slipping when the maximum traction is put upon the belt.

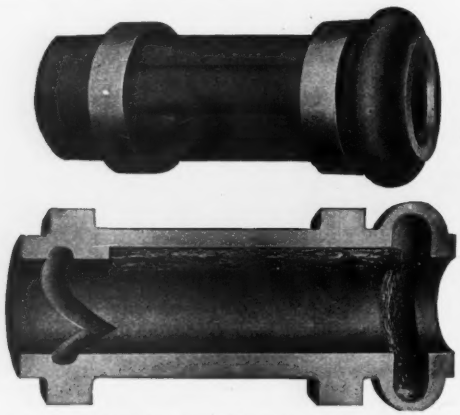


FIG. 3. ROBERTS SELF-OILING LOOSE BUSHING

The pulley is made up of parts which are stamped by dies and when finished is not turned up on a lathe. These facts and the fact that the parts are interchangeable and symetrically placed insures a balanced pulley. To insure correctness, however, all pulleys of the larger sizes are tested for balance.

American pulleys are also adapted for split, tight and loose pulley sets, the loose pulley being equipped with Roberts self-oiling loose bushing and Fauls lubricator.

THE INDEPENDENCE PULLEY

Dodge Manufacturing Co., Mishawaka, Ind.

IN THE MANUFACTURE of the Independence wood split pulley, perfectly dry lumber is used which is held together entirely by glue. The segments making up each ring course in the rim are joined end to end by fitted dovetailed blocks. The middle portion of the rim in width equal to the breadth of the arm ends is first made up by gluing together several rim rings, breaking joints with segments for successive rings, and putting the whole under heavy pressure before the glue has begun to set. When the glue is thoroughly dried the rim is reamed out for interior finish.

Next, the rim is sawed into halves notched with dovetailed slots for the arm ends and bored to receive anchor bolts. An irregular method of sawing the rims in halves is employed for the express purpose of preventing the possibility of mismating the pulley in fit-

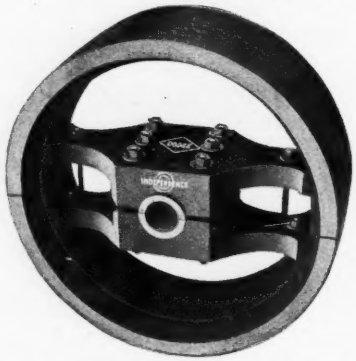


FIG. 1. INDEPENDENCE WOOD SPLIT PULLEY

ting it on the shaft. The hub valves are solid blocks glued into the flat face of the heavy arms whose ends are sawed to fit the dovetailed slots on the rim face.

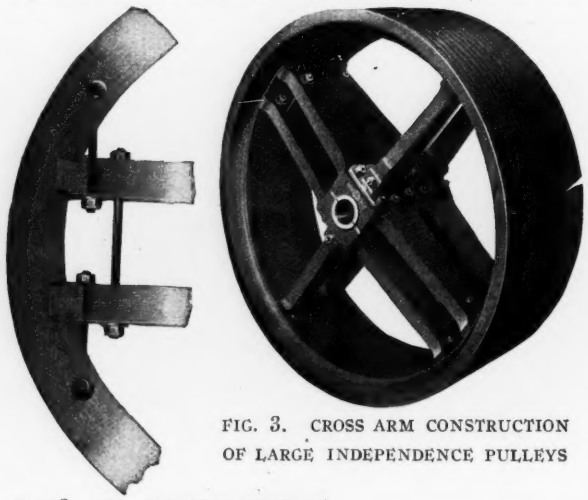


FIG. 3. CROSS ARM CONSTRUCTION OF LARGE INDEPENDENCE PULLEYS

FIG. 2. RIM AND ARM JOINT OF INDEPENDENCE PULLEY

The hub blocks are wider than the arm ends, being nearly equal to the total face width of the pulley while the arms are narrowed to fit the middle section of the

FIG. 4. IRON CENTER WOOD RIM PULLEY

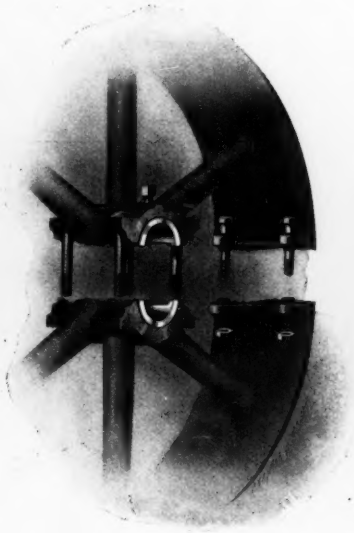
rim. Slender wedges driven in with the glue lock the ends of the arms firmly in the dovetailed notches. In addition to these where the arms are secured to the rims by anchor bolts whose rim ends terminate in special nuts slipped into place through small holes bored into the edge of the rim to meet the bolt holes

at right angles to the arm line from the inside of the rim.

Passing through the arms just inside the anchor bolts are what are termed the rim bolts, their duty being to hold the meeting ends of the rim halves in close contact. The rim is now built out to the full width by gluing on 2 ring courses at each side and after this is done the pulley face is turned either crowned or straight as may be desired. The outer rim courses are then sawed with straight kerfs which, with the wavy sawings of the inner portions, make an interlocking fit which contributes to the strength and positiveness of the rim generally. The pulley is now complete with the exception of a slight balance which may be necessary, and hardening of the rim face which is done by special means.

The basis of the bushing system is the use of standard bores for all pulleys within certain ranges of diamter and adjusting these to all smaller sizes of shafting by the insertion of bushings in standard bores.

In sizes up to and including 8 in. diameter the Independence pulley is made solid with plain bore nonmismating split and slotted head bolts for tightening by screw driven in counterbores beneath the face. Pulleys 9 to 36 in. in diameter inclusive are built with



DODGE SPLIT IRON PULLEY

plain double arms. In these sizes the rim halves have ample stiffness and strength for carrying all driven loads and belt strains. For diameters 38 in. and more cross arms are introduced as strut bars to add to the strength of the rim arch. These arms do not assume any of the driving load but do resist in the collapsing pressure of heavy belts under high tension.

A more recent type of pulley manufactured by this company is an iron center with a wood rim. It was designed particularly for cases where a high speed wood pulley is deemed necessary and for exceptionally hard service. The rim construction is similar to that employed in the wood pulleys, this rim being mounted on a cast-iron spider. By this construction the shrinkage strains that exist in heavy iron pulleys at the junction of the arms and rim are eliminated.

This type of pulley is made in both solid and split form.

DODGE STANDARD SPLIT IRON PULLEY

Dodge Manufacturing Co., Mishawaka, Ind.

A DISTINCTIVE FEATURE of this pulley is that the rim is cast whole, then split by fracture at the parting line. The pulley is mounted on the shaft and the fractured edges of the rim are matched and bolted. They fit together so tightly that the pulley has practically a solid rim. Being made of cast iron, the pulleys are nonflexible and will stay true and in balance.

These pulleys can be erected or taken down with little difficulty, yet when placed upon the shaft are held firmly by compression reinforced by 2 setscrews. By use of interchangeable bushings which can be supplied, the pulleys can be fitted to all different sizes of shafting within reasonable range, thus adapting them to changes in the plant equipment.

JONES PAPER PULLEYS

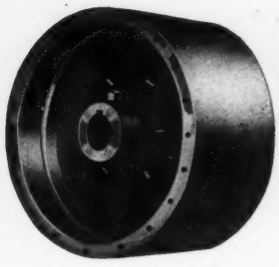
W. A. Jones Foundry & Machine Co., Chicago, Ill.

PAPER PULLEYS manufactured by this company are designed particularly for electric service and are furnished in all standard sizes up to 50 in. in diameter. The are made entirely of compressed paper with cast-iron hub bored and key seated, or set screwed as desired. These pulleys are made either with straight or crown face and in special sizes up to 72 in. in diameter and 36-in. face.

JONES HEAVY BELT TIGHTENERS

W. A. Jones Foundry & Machine Co., Chicago, Ill.

TWO FORMS OF BELT tighteners are illustrated here. Figure 1 shows an iron frame tightener complete



JONES PAPER PULLEY

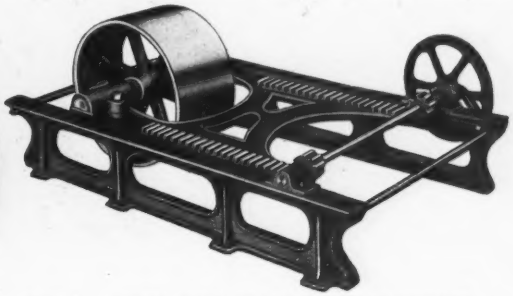


FIG. 1. JONES IRON FRAME BELT TIGHTENER

which is used for floor or overhead service and sets upon an iron frame upon which is mounted the belt pulley

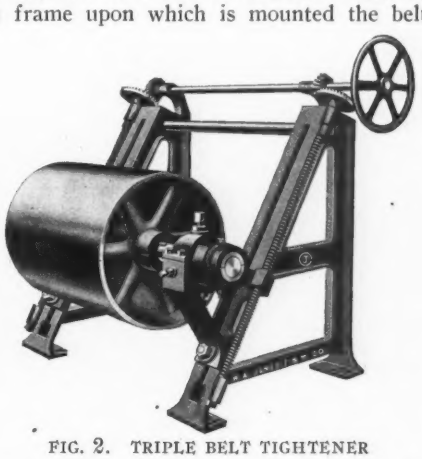


FIG. 2. TRIPLE BELT TIGHTENER

supported in 2 bearings, these are attached rigidly to a pair of racks, which are engaged by spur gears upon

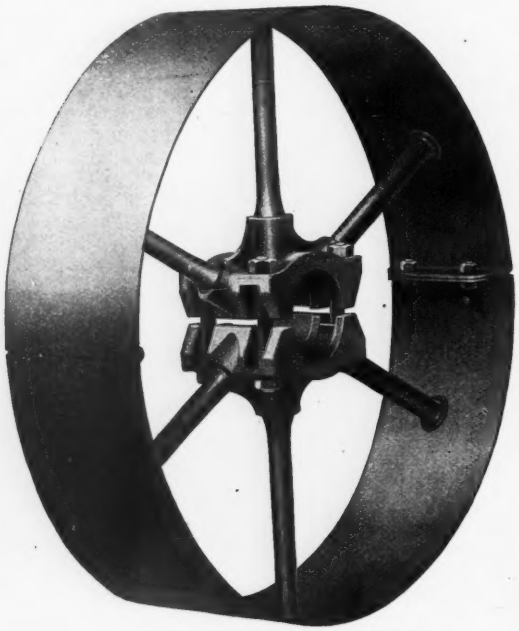
the shaft of a hand wheel which is locked in position by a ratchet wheel and dog. These are furnished in sizes for pulleys of 12 by 9 to 42 by 38 in.

In Fig. 2 is illustrated a type which is capable of doing triple belt service. It can be used either on horizontal or vertical belts and is held in position by a screw gear. The sizes of pulley supplied with these tighteners range from 24 by 21 to 36 by 49 in.

KEYSTONE AND ONEIDA STEEL PULLEY

Oneida Steel Pulley Co., Oneida, N. Y.

THE KEYSTONE STEEL Pulley has a rim varying in thickness from ¼ to ⅜ in., in various sizes of pulleys. It is made without a beaded rim thus making it of value for use in textile mills or wood-working plants where the dust is continually settling on every available place. They allow the use of interchangeable



THE KEYSTONE STEEL PULLEY

cast-iron bushings, and being split pulleys are easily adjusted to the shaft. The sizes range from the smallest to the largest that occasion demands.

Keystone pulleys are made of specially treated steel making them adaptable in many places where other materials can not be used to advantage.

The illustration affords a good, detailed idea of the Keystone.

In the manufacture of the Oneida steel pulley the large steel sheets are cut into strips of the desired width by a large shear, the ends are squared and rivet holes for arms are punched. Flanges are turned up on the sides of these strips and the flat rim is rolled into a semicircle, at the same time the flanges are turned under to form a bead. The rim is also crowned during this operation if a crown faced pulley is desired. At the same time blanking, forming and finishing the arms and hubs is going on.

In assembling, first a malleable iron yoke is put into the hub to give additional strength, the spokes are riveted to this hub and the fishplates are placed in position at the outer ends of the arms. Then the spider is riveted to the rim making a complete half pulley, although in a large pulley arm braces are added at this point. The halves are bolted together and the pulley is trued.

The fishplate is placed at the end of arms of pulleys over 20 in. in diameter. It broadens the bearing surface for the rim, making a double thick rim.

In the case of extra large bores the entire hub is made of malleable iron. Bushings are made of cast iron and are accurately finished.

Oneida pulleys are made from 6 to 120 in. in diameter with a 2 to 40 in. face and 1 to 8½-in. hubs.

THE PHILIPS PRESSED STEEL PULLEY

Philips Pressed Steel Pulley Works, Philadelphia, Pa.

THE RIM IS FORMED of a single sheet of steel. It consists of a double thickness of metal flanged on both sides and extending toward the center where at right angles to the face both ends of the sheet project

FIG. 1. HUB AND SPIDER OF PHILIPS PRESSED STEEL PULLEY

and form a rigid central rib, to which the spider is riveted. This construction does not destroy the face with grooves or rivets.

The arms are of bridge construction, which makes it impossible to center the strain upon any one set of arms; the strain being equally divided over the entire circumference of the pulley rim, and these being placed both sides of the hub help materially to strengthen the outer edges of the rim.

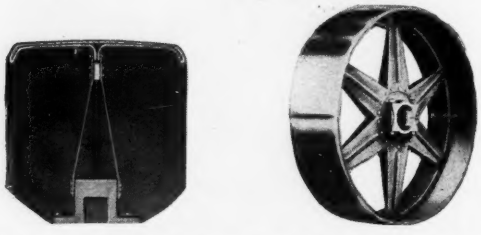


FIG. 2. RIM CONSTRUCTION AND COMPLETED PHILIPS PULLEY

The rim lugs extend over the entire width of the pulley, making the rim a strong part of the pulley. In forming the flange on the outer edges of the rim strength of the rim is increased.

A cast-iron hub is employed which is strong and is bored and reamed, assuring perfect trueness of fit upon shaft where its diameter is the same as bore of hub.

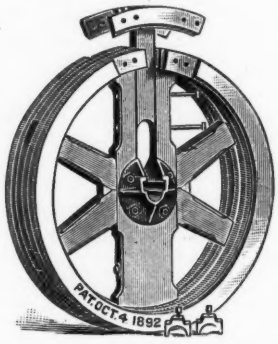
The bushings are also bored and lathe turned, preventing any untrueness in the running of the pulley. They are made interchangeable and vary in size from a 1-16 in. up to the full bore of the hub.

IMPROVED READING IRON CENTER WOOD PULLEY

Reading Wood Pulley Co., Reading, Pa.

THE SPECIAL features of this pulley, as will be noted by the illustration, are that it has a practically solid rim with the exception of a small section which can be removed for placing it upon the shaft, also that it has an iron center and therefore may be held upon the shaft either by friction or keyed to suit the desires of the engineer in this direction.

The section which is removed is taken out at the end of one of the main arms, which is made large enough



IMPROVED READING IRON CENTER WOOD PULLEY

to allow for this section being removed. When placed upon the shaft the section is put back in place and securely bolted thus preventing undue strain and allowing the pulley to be balanced perfectly. The rim is made of poplar, which has a high frictional resistance and makes a wheel exceedingly light in weight.

REEVES WOOD SPLIT PULLEY

Reeves Pulley Co., Columbus, Ind.

THE REEVES WOOD SPLIT Pulley in practically its present design and finish has been manufactured since 1888. It has the bar-arm construction, and by means of its interchangeable bushing system one pulley will fit 35 different sizes of shaft.

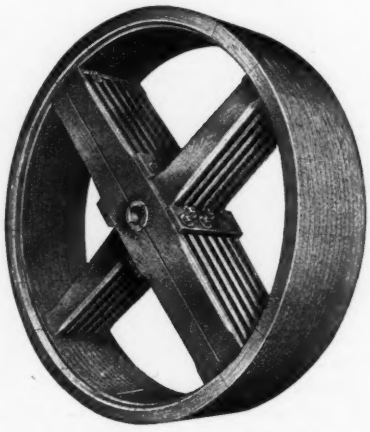


FIG. 1. REEVES SPLIT WOOD PULLEY

Standard "The Reeves" wood split pulley are made in sizes from 3 to 120 in. diameter, and special pulleys any size up to 32 ft. diameter, and width of face.

Pulleys 3 to 5 in. diameter are made block type. Pulleys 5 and 6 in. diameter are made either block or clamp type, and pulleys 8 and 9 in. diameter of block type only. Pulleys 10 to 34 in. diameter are of the single arm design and from 36 to 80 in. diameter of the double arm construction. Above this a similar construction is employed by increasing the number of arms, thus increasing indefinitely and proportionately the strength in the same ratio as in the smaller sizes.

The bushing is made in quarters, insuring a perfect bearing on the shaft.

The rim segments are cut short, thus making not only a stronger rim than longer segments but preventing them from getting out of true.

The arms are made up of selected hardwood, and composed of a series of pieces dressed to exactly the

FIG. 2. METHOD OF FASTENING ARM IN RIM OF REEVES PULLEY

same thickness as the rim segments, placed edgewise with the strain and built up in alternate layers with the rim as shown by Fig. 2, nailed and glued into it, thereby becoming an integral part thereof. This construction assures as great strength in this vital point as in any part of the pulley, and by reason of the edgewise construction the arms cut the air.

ROCKWOOD PAPER PULLEYS

The Rockwood Mfg. Co., Indianapolis, Ind.

THE ROCKWOOD PAPER PULLEY is built up of thin sheets of straw fiber cemented together and compressed under hydraulic pressure. These sheets of straw fiber are not compressed from a mass of paper scrap but are formed very much in the same way paper is made, and the result is a sheet which has definite longitudinal grain or fiber. In the manufacture of the pulley, the disks and rings forming the web and rim are cut from these sheets. They are assembled so the edges of the sheets form the face of the pulley. The ends of the fibers thus coming directly in contact with the belt. In assembling, the direction of the grain or fiber of alternate sheets is crossed so that all parts of the pulley face fibers project outward, each individual fiber being thus in a position to exert a direct pull on the belt.

The rims of these pulleys are strengthened by wooden dowel pins that extend through the rim and web, the latter corresponding to the arms of the cast-iron pulley. The webs are fastened to cast-iron hubs by clamping them between bolts between flanges secured to the hub. These pullyes require little or no balancing and are not subjected to the irregular centrifugal strains caused by balance weights.

Rockwood pulleys are made up to a maximum diameter of 72 in. and within any reasonable combination of face widths, hub lengths, diameter of bore and over hangs. They are made with either single or double web and are attached to the shaft by means of keys or set screws.

SHAFTING

MATERIALS, STRENGTH AND EQUIPMENT

MATERIALS MOST COMMONLY USED in making shafting are wrought iron and steel, though in some cases where the shaft is short and well supported, such as jack shafts, cast iron is employed. Originally shafts were made of wood, but today these are rare and represent only the crudest sort of means for transmitting power. It is therefore within the scope of this article to take up a discussion of wrought iron and steel shafting only, as these are the only materials employed for transmitting power to any distance.

The choice between wrought iron and steel lies largely with the fancy of the engineer, though for shafting transmitting a small amount of power wrought iron is almost invariably used, as the diameter of a steel shaft would be so small that it would become impractical, owing to the increased number of supports needed, or if the diameter be increased beyond that necessary to carry the required power its cost

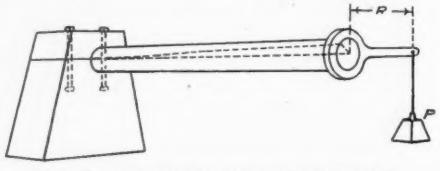


FIG. 1. TWISTING STRAIN OF SHAFT

would be increased so much more than wrought iron that it would become impractical from this standpoint. At the other extreme, that is, where a great amount of power is to be transmitted, steel shafting is employed as its diameter and weight will be considerably less than that of wrought iron for the same power transmitted.

Twisting Load

STRAINS to which a shaft is subjected come under 2 heads. These are the twisting and bending strains. The principal strain of course is that due to the twisting action of the pulley, and a study of its action in detail is essential in order that we may get a clear conception of what is actually taking place within the fibers of the shafting and thus be able to determine the power which the shaft is able to transmit.

Considering a shaft that is fixed rigidly at one end, and at the other has a horizontal lever attached to it whose length is R. At the end of this lever is attached a weight P. This arrangement is shown in Fig. 1. It will be seen that in order to keep the shaft from twisting, the fibers of the shaft must exert a combined moment of force equal to the product of R times P.

Suppose that the strain put upon a very small unit of area of the shaft, A, to be p, then the resisting moment of this area is equal to p times its distance from the center of the shaft. From this it is evident that the resisting moment of a unit area of the shaft is proportional to its distance from the center, and by mathematical calculation it has been shown that for round shafts the total resisting moment becomes 3.1416 times the shearing strength of the material used, times the cube of the diameter, divided by 16. By means of this rule we are therefore able to determine the power which the shaft will transmit, knowing the radius of the pulley and the shaft diameter, the shearing strength of steel being 75,000 lb. to the square inch, of wrought iron 50,000, and of cast iron 25,000. Furthermore, if we know the speed of the shaft we are able to determine the horsepower transmitted by multiplying the pull in pounds by the speed of the belt in feet per minute, and dividing the product by 33,000.

The rule above gives the breaking strength of the shaft, for we took the ultimate shearing strength of the material used in the shaft, so for our purposes, it is necessary to use a shearing strength considerably less in order to get a safe working strain. This for steel is taken as 12,000 lb., for wrought iron 8000, and for cast iron 4000.

Taking these factors into consideration, in the above rule, we find the diameter of the shaft by dividing the horsepower to be transmitted by the revolutions

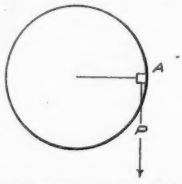


FIG. 2. STRAIN ON SMALL AREA

per minute, extracting the cube root and multiply by 2.984 for steel; for iron multiply by 3.422, and for cast iron by 4.297.

In order to get this rule into a working form the diagrams in the Practical Tables have been worked out for various horsepowers and speeds to give the diameter of shaft necessary. Thus, knowing 2 of these 3 quantities, by the use of the diagrams, the other dimension can easily be obtained. In these diagrams, however, a larger factor of safety has been used in order to take care of the bending strain. For cold rolled iron the multiplier used for shafts with bearings on 8-ft. centers is 3.68 and for turned iron under the same condition the multiplier used is 4.48, these values being given by several authorities as representing best practice.

Hollow Shafting

BY an analysis of the strains which take place within a shaft as given above, it will be noted that, since the moment of force which a given area of the shaft is able to transmit varies as its distance from the center, the actual material employed in the shaft can be made less and still transmit the same amount of power by making the shaft hollow. By a comparison of the solid and the hollow shafts it has been demonstrated that they will be of equal strength when the difference between the fourth powers of the outside and inside diameters divided by the outside diameter of the hollow shaft is equal to the cube of the diameter of the solid shaft.

There are certain advantages to be had by the use of hollow shafts in that their weight is considerably less, and for this reason, and also that the bending

strength is considerably decreased owing to the increased diameter, the bearing or the supports can be placed further apart. Where the power is great a hollow shaft becomes so large that the bearings become abnormally large and over expensive.

Distance Between Supports

THE proper distance between bearings or supports of a shaft is governed by the deflection which should never exceed 0.01 in. per foot of length. This in turn is dependent upon the weight or diameter of the shaft, the material of which it is made, and the location of the pulleys with reference to the bearings.

For simply transmitting power without weight Table I, computed by J. B. Francis, gives the greatest distance between bearings where iron and steel shafting are employed, the distance being in feet.

TABLE I. GREATEST ALLOWABLE DISTANCE BETWEEN SHAFT BEARINGS

DIAM. OF SHAFT IN IN.	DISTANCE BETWEEN BEARING, FT.	
	WROUGHT IRON	STEEL
2	15.46	15.89
3	17.70	18.19
4	19.48	20.02
5	20.99	21.57
6	22.30	22.92
7	23.48	24.13
8	24.55	25.23
9	25.53	26.24

TABLE II. DIAMETER OF SHAFT TO CARRY LOAD MIDWAY BETWEEN BEARINGS

DIAM. OF HEAD SHAFT	DIAM. OF SHAFT FOR CARRYING LOAD AT CENTER OF BAY							
	2½ FT.	3 FT.	3½ FT.	4 FT.	5 FT.	6 FT.	8 FT.	10 FT.
IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.
2	2 1/8	2 1/4	2 3/8	2 1/2	2 3/4	2 3/4	2 7/8	3
2 1/2	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/8	3 3/8	3 5/8
3	3	3 1/8	3 1/4	3 3/8	3 1/2	3 3/4	4	4 1/4
3 1/2		3 1/2	3 5/8	3 3/4	4	4 1/4	4 1/2	4 3/4
4		4	4 1/8	4 1/4	4 1/2	4 3/4	5 1/8	5 3/8
4 1/2			4 1/2	4 5/8	4 7/8	5 1/8	5 1/2	5 7/8
5			5	5 1/8	5 3/8	5 5/8	6	6 1/2
5 1/2				5 5/8	5 7/8	6	6 1/2	6 7/8
6				6	6 1/4	6 1/2	7 1/8	7 1/2

For ordinary line-shaft work, however, this table is of no value as it is necessary to place pulleys at various points along the shaft without reference to the bearings. The general rule for line shafts is to place the bearings 8 ft. apart, but Table II given by Kent will be of value as it gives the diameter of shaft necessary to carry the load at the center between bearings, compared with the diameter for head shafting. Expressed as a rule where shafting is used for transmission alone, the distance between bearings is taken as the cube root of the product of 720 times the diameter squared. Where the shaft carries a number of pulleys placed at various points between bearings, the distance is equal to the cube root of (140 times the diameter squared).

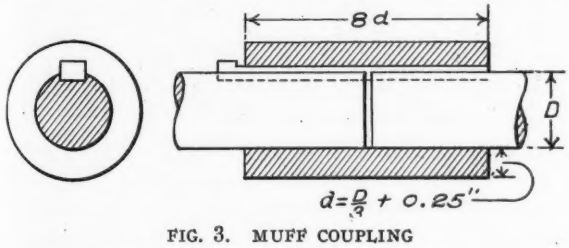


FIG. 3. MUFF COUPLING

Proper Speed

THE character of the work to be performed by a line shaft determines almost entirely the speed at which it should be driven. Another factor entering into the choice of speed is the speed of the main driver and the diameter of the main driven pulley.

For machine shops the speed most generally employed ranges between 120 and 180 r.p.m. In wood working shops this is increased from 250 to 300 r.p.m., and in cotton mills and the like the line shafts run from 300 to 400 r.p.m.

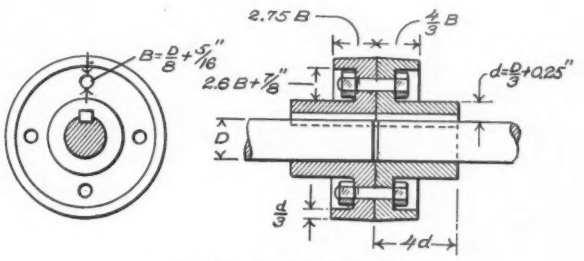


FIG. 4. PLATE COUPLING

While it is less expensive to install a plant with line shafting running at high speed, owing to the decreased cost of shafting, belts, pulleys, etc., the cost of maintenance is increased considerably owing to the increased wear upon the bearings, the vibration of the shaft tends to destroy its alinement, and the general wear and tear of the whole system increases.

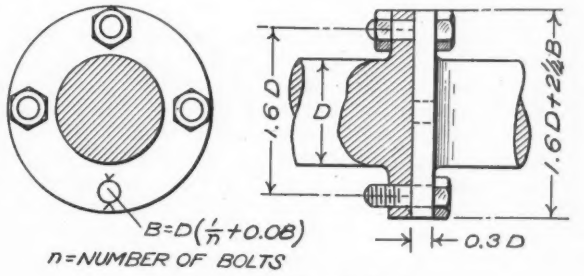


FIG. 5. FORGED COUPLING

Couplings

WHERE it is found desirable to extend a shaft or in cases where the shafting runs the entire length of the room without sufficient space at the end to remove pulleys, clutches, and the like, some form of coupling is a convenience well worth employing. There are upon the market a large number of different styles of couplings, but they all may be considered under one of the following 5 types.

Muff couplings, as the name would imply, consist simply of a ring which slips over the adjoining ends

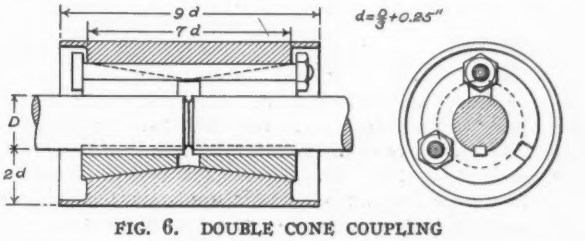


FIG. 6. DOUBLE CONE COUPLING

of the 2 shafts, the joint being fitted with a key which runs the entire length of the coupling. The thickness d of the hub Fig. 3, is equal to 1-3 the diameter of the shaft plus 0.25 in. and the length of the muff is 8 times the thickness.

Plate couplings, such as shown in Fig. 4, are used for heavy shafts and consist of 2 parts, each keyed to the end of a shaft with the flanges bolted together. The thickness of the hub equals 1-3 the diameter plus 0.25 in., the same as for the muff coupling, and the

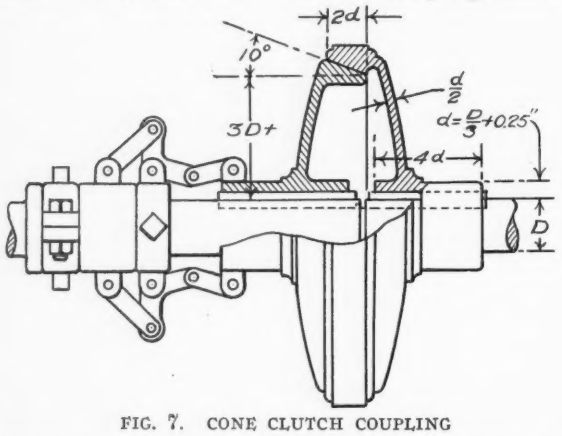


FIG. 7. CONE CLUTCH COUPLING

length of the hub equals 4 times the thickness, this being for each half of the coupling. The halves are either forced or keyed to the shaft before it is put into place, and after alinement has been made the plates are bolted together. The number of bolts employed equals 0.8 times the diameter of the shaft plus 2.

Forged flange couplings are made by upsetting the end of the shaft so as to form a disk at the end whose diameter, according to Seaton, is equal to 1.6 times the diameter of the shaft plus 2.25 times the diameter of the bolt used. The diameter of the bolt circle equals 1.6 times the diameter of the shaft and the thickness of each flange equals 0.3 times the diameter of the shaft.

The double cone coupling shown in Fig. 6, is somewhat more complicated in its construction than any

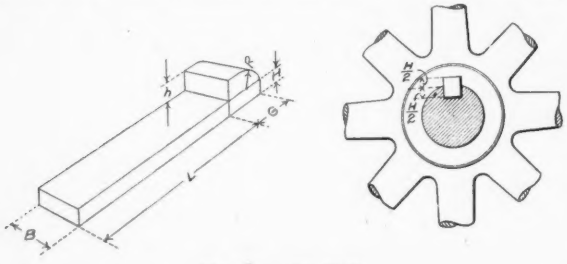


FIG. 8. GIB KEY

of the foregoing, but presents the advantage that it is easily removable and allows for some variation in the diameter of the shafts upon which it may be placed. It consists of 2 hollow split cones which fit into a sleeve whose interior surface is a double cone shaped to conform to the surface of the interior cones. The coupling is provided with 3 bolts which run the entire length of the coupling and draw the interior cones together thus clamping them tightly against the shaft and as an extra precaution the coupling is provided with a key which runs its entire length. The illustration shows the dimensions employed, using D as the diameter of the shaft.

Clutch couplings are employed where it is desirable to disengage one section of the shafting from the other and a general form of cone type of coupling is shown in Fig. 7. The thickness of the hub in this case is the same as that for the muff coupling, being equal to the diameter of the shaft divided by 3, plus 0.25 in. The length of each half of the coupling is also as before, 4 times the thickness of the hub. The radius of the flange to the contact surface should not be less than 3 times the diameter of the shaft, and the contact should make an angle not less than 10 deg. with the center line of the shaft. In this case half of the coupling is forced or keyed to one shaft, while the other is fitted loosely upon the shaft which is provided with a feather key, and by means of a lever arrangement and toggles this half of the coupling may be shifted upon the shaft so as to engage or disengage with the other half of the coupling.

TABLE III. KEY DIMENSIONS FOR VARIOUS SIZED SHAFTS

SHAFT DIAM. IN.	WIDTH IN	THICKNESS IN	SHAFT DIAM IN	WIDTH IN	THICKNESS IN	SHAFT DIAM. IN	WIDTH IN	THICKNESS IN
½	7/32	3/16	3 1/4	3/4	7/16	6 3/4	1 5/8	3/4
5/8	1/4	3/16	3 1/2	13/16	7/16	7	1 7/16	13/16
3/4	3/32	3/16	3 3/4	13/16	1/2	7 1/4	1 1/2	13/16
7/8	9/32	7/32	4	7/8	1/2	7 1/2	1 9/16	7/8
1	5/16	1/32	4 1/4	15/16	9/16	7 3/4	1 9/16	7/8
1 1/8	11/32	1/4	4 1/2	1	9/16	8	1 5/8	7/8
1 1/4	3/8	1/2	4 3/4	1	9/16	8 1/4	1 5/8	15/16
1 3/8	3/8	1/4	5	1 1/16	5/8	8 1/2	1 3/4	15/16
1 1/2	13/32	1/4	5 1/4	1 1/8	5/8	8 3/4	1 3/4	15/16
1 3/4	7/16	5/16	5 1/2	1 3/16	5/8	9	1 3/4	1
2	1/2	5/16	5 3/4	1 3/16	11/16	9 1/4	1 7/8	1
2 1/4	9/16	5/16	6	1 1/4	11/16	9 1/2	1 7/8	1 1/16
2 1/2	5/8	7/16	6 1/4	1 5/16	3/4	9 3/4	2	1 1/16
2 3/4	5/8	3/8	6 1/2	1 3/8	3/4	10	2	1 1/16
3	11/16	7/16						

Clutch couplings are employed where it is desirable to disengage one section of the shafting from the other and a general form of cone type of coupling is shown in Fig. 7. The thickness of the hub in this case is the same as that for the muff coupling, being equal to the diameter of the shaft divided by 3, plus 0.25 in. The length of each half of the coupling is also as before, 4 times the thickness of the hub. The radius of the flange to the contact surface should not be less than 3 times the diameter of the shaft, and the contact should make an angle not less than 10 deg. with the center line of the shaft. In this case half of the coupling is forced or keyed to one shaft, while the other is fitted loosely upon the shaft which is provided with a feather key, and by means of a lever arrangement and toggles this half of the coupling may be shifted upon the shaft so as to engage or disengage with the other half of the coupling.

The installation of a coupling upon a line shaft requires the utmost care to see that the shaft is in perfect alinement or trouble is sure to follow. There is considerable danger connected with the use of couplings in that there are frequently projecting points such as bolt heads, nuts and so forth, which are liable to catch upon belts, thus causing the belt to be ruined, or the alinement of the shaft to be destroyed as well as other serious consequences.

TABLE IV. DIMENSIONS OF GIB KEYS

BORE & SHAFT DIAMETER	WIDTH OF KEY B	HEIGHT OF KEY H	DEPTH KEY SEAT	HEIGHT & RAD. OF GIB	WIDTH OF GIB G	SAFE TWISTING MOMENT ON KEY PER INCH OF LENGTH FOR S= 5000	7,500	10,000
15/16 TO 1 1/8	1/4	3/16	3/32	3/16	1/4	630	940	1,250
1 3/16 TO 1 3/8	3/8	1/4	1/8	3/16	3/8	1,170	1,760	2,340
1 7/16 TO 1 5/8	3/8	1/4	1/8	3/16	3/8	1,410	2,110	2,810
1 11/16 TO 1 7/8	1/2	5/16	5/32	1/4	1/2	2,190	3,280	4,380
1 15/16 TO 2 1/8	1/2	3/8	3/16	1/4	1/2	2,500	3,750	5,000
2 3/16 TO 2 3/8	5/8	3/8	3/16	3/8	5/8	3,520	5,270	7,030
2 7/16 TO 2 5/8	5/8	7/16	7/32	3/8	5/8	3,910	5,860	7,810
2 11/16 TO 2 7/8	3/4	1/2	1/4	3/8	3/4	5,160	7,730	10,313
2 15/16 TO 3 1/8	3/4	1/2	1/4	3/8	3/4	5,620	8,420	11,250
3 3/16 TO 3 3/8	7/8	9/16	9/32	1/2	7/8	7,110	10,660	14,220
3 7/16 TO 3 5/8	7/8	5/8	5/16	1/2	7/8	7,660	11,480	15,310
3 11/16 TO 3 7/8	1	5/8	5/16	1/2	1	9,380	14,060	18,750
3 15/16 TO 4 1/8	1	11/16	11/32	1/2	1	10,000	15,000	20,000
4 3/16 TO 4 3/8	1 1/8	11/16	11/32	5/8	1	11,950	17,930	23,910
4 7/16 TO 4 3/4	1 1/8	3/4	3/8	5/8	1	12,660	18,980	25,310
4 13/16 TO 5 1/4	1 1/4	7/8	7/16	5/8	1 1/4	15,620	23,440	31,250
5 5/16 TO 5 3/4	1 1/8	7/8	7/16	3/4	1 1/4	18,910	28,360	37,810
5 13/16 TO 6 1/4	1 1/2	1	1/2	3/4	1 1/2	22,500	33,750	45,000
6 5/16 TO 6 3/4	1 1/2	1	1/2	7/8	1 1/2	24,380	36,560	48,750
6 13/16 TO 7 1/4	1 1/2	1	1/2	7/8	1 3/4	26,250	39,380	52,500
7 5/16 TO 7 3/4	1 5/8	1	1/2	1	1 3/4	30,470	45,700	60,940
7 13/16 TO 8 3/4	1 3/4	1 1/8	9/16	1	2	36,090	54,140	72,190
8 13/16 TO 9 3/4	2	1 1/4	5/8	1 1/8	2	46,250	69,380	92,500
9 13/16 TO 10 3/4	2 1/4	1 1/2	3/4	1 1/4	2	57,660	86,480	115,320
10 13/16 TO 11 3/4	2 1/2	1 1/2	3/4	1 1/4	2	70,310	105,470	140,630
11 13/16 TO 12 3/4	2 1/2	1 1/2	3/4	1 1/4	2	76,560	114,840	153,130

Keys

IN order to keep pulleys, couplings, or clutches from turning on a shaft either set screws or keys are employed. The holding power of set screws is so small in comparison to keys that in nearly all cases of line shafts or head shafts keys are employed in preference to set screws. They are usually made of mild steel with

a shearing strength in the neighborhood of 60,000 lb. per sq. in.

There are 2 entirely distinct classes or systems of keys, the first and most common being the fastening key with a width about ¼ the shaft diameter, and the depth 5/8 to 1/3 the width. These keys are tapered and set in the keyway all over, and in this way have 2 functions, that of keeping the keyed-on member from turning on the shaft, also keeping it from having an endwise motion.

The second class of keys fit on the sides only, and are not tapered. They will thus have some clearance in the radial direction and drive by their shearing strength only. The former class of keys, fitting as it does the entire keyway, will act as a strut.

In regard to the proportions of keys authorities differ considerably as to those most practical for the purpose. It may be said however that for keys used to drive a shaft or to transmit its entire power in all cases authorities base their proportions upon the diameter of the shaft. For instance E. G. Parkhurst gives the rule that the width of key equals 1/8 the

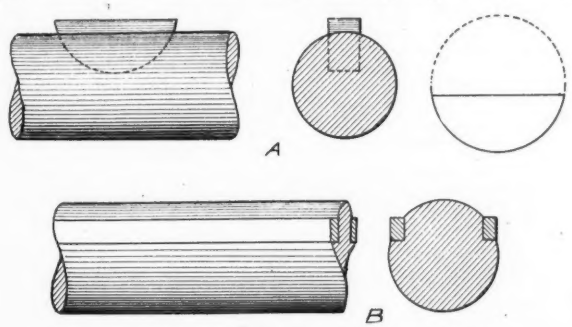


FIG. 9. FORMS OF WOODRUFF AND ANGLE KEYS

diameter of the shaft, its depth equals 1/9 the diameter of the shaft, and the taper is 1/8 in. to the foot. The rule customary in Michigan saw mills is that the keys are of square section the sides being ¼ the diameter of the shaft. Unwin gives as the best proportion a width equal to ¼ the diameter of the shaft plus 1/8 in., thickness equals 1/8 the diameter plus 1/8 in.

These dimensions are all, of course, too high for keys that only transmit a part of the load of the shaft. For all such cases a safe rule is to ascertain the pull of the belt upon the pulley, multiply this by the radius of the pulley, divide the product by the radius of the shaft, divide this again by the length of the pulley hub and by the safe working shearing strength of the key, the quotient will then be the width of the key in inches.

In Table III are given the width and thickness of keys for various sized shafts, the key being fitted on all sides, used as standard in the U. S. Navy.

Somewhat different proportion of key is employed where it is deemed necessary to remove the keyed-on member occasionally, also where the key must keep the pulley from an endwise motion. This class of key is known as a gib key and is illustrated in Fig. 8. Its proportions as given by F. D. Buffum in Machinery, are to have the width ¼ the diameter of the shaft up to 6 in., above which it is 0.211 times the diameter, taken to the nearest 1/8 in. The gib has a width G, equal approximately to the width of the key, and the height h, also the radius R, equals 1/8 the diameter of the shaft, the minimum value being 3/16 in.

The height of the key equals 1/6 the diameter of the shaft up to 6 in., then it becomes 1/8 the diameter.

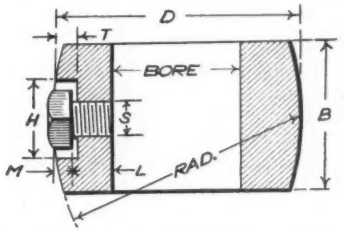


FIG. 10. COMMON FORM OF COLLAR

The length of the key is the length of the hub plus ½ in. The taper in this case is the same as given before, that is 1/8 in. per foot. From these dimensions

TABLE V. DIMENSIONS OF COLLARS

BORE	B	D	H	L	M	S	T
1 7/16	1 5/8	2 3/4	7/8	1 3/32	3/4	3/8	1/4
1 1/2	1 3/4	3	7/8	1 9/32	3/4	3/8	1/4
1 1/16	1 7/8	3 1/4	1	1 3/32	1/4	1/2	5/16
1 11/16	2	3 3/8	1 1/8	1 3/32	1/4	5/8	3/8
2 3/16	2 1/8	4	1 1/4	2 1/32	5/16	5/8	3/8
2 7/16	2 1/4	4 3/8	1 1/4	2 5/32	5/16	5/8	3/8
2 11/16	2 1/2	4 3/4	1 1/2	2 5/32	3/8	3/4	7/16
2 15/16	2 5/8	5 1/4	1 1/2	2 9/32	3/8	3/4	7/16
3 3/16	2 3/4	5 3/4	1 1/2	1	3/8	3/4	7/16
3 7/16	2 7/8	6 1/4	1 3/4	1 1/16	7/16	7/8	1/2
3 11/16	3	6 3/4	1 3/4	1 3/16	7/16	7/8	1/2
3 15/16	3 1/8	7 1/4	1 3/4	1 5/16	7/16	7/8	1/2
4 3/16	3 1/4	7 3/4	2	1 7/16	1/2	1	9/16
4 7/16	3 3/8	8 1/4	2	1 1/2	1/2	1	9/16
4 11/16	3 5/8	8 3/4	2 1/4	1 1/2	9/16	1 1/8	9/16
5 7/16	3 7/8	9 1/4	2 1/4	1 1/2	9/16	1 1/8	9/16
5 11/16	4 1/8	9 3/4	2 1/4	1 1/2	9/16	1 1/8	5/8
6 7/16	4 3/8	10 1/4	2 1/4	1 1/2	9/16	1 1/8	5/8
6 11/16	4 5/8	10 3/4	2 1/2	1 7/16	5/8	1 1/4	11/16
7 7/16	4 7/8	11 1/4	2 1/2	1 7/16	5/8	1 1/4	11/16
7 11/16	5 1/8	11 3/4	2 1/2	1 7/16	5/8	1 1/4	11/16
8 7/16	5 3/8	12 1/4	2 1/2	1 7/16	5/8	1 1/4	11/16
8 11/16	5 5/8	12 3/4	2 1/2	1 7/16	5/8	1 1/4	11/16
9 7/16	5 7/8	13 1/4	3	1 5/16	3/4	1 1/2	13/16
9 11/16	6 1/8	13 3/4	3	1 5/16	3/4	1 1/2	13/16

the accompanying table has been calculated, giving the safe twisting moment on the key per inch of length.

Feathers or splines which are keys upon which a sleeve or collar may slide in a direction parallel to the length of the shaft while at the same time compelled to rotate with it, have proportions somewhat different from those given above. It is quite common in this case to place the key on edge, that is, with the greater of the 2 dimensions in the radial direction of the shaft. The other dimensions are practically the same as given above, except that in this case no taper is used and a driving fit is not employed.

There are, in addition to the forms mentioned above, various other styles of keys used, such as the Woodruff shown in Fig. 9A, or those fitting into an angle keyway, Fig. 9B, also round keys and so forth. These however, are of so little use today that their consideration in this article is omitted.

Collars

TO keep a line shaft from having too much end play it is common practice to employ a collar at each end near a bearing, giving sufficient room for end play of the shaft to keep it from spoiling the bearings, but preventing this from becoming so large as to throw belts off. In many cases this same effect is accomplished by placing a belt pulley near a bearing and letting the hub act as a collar. This, however, is not always advisable as the bearing is apt to throw oil upon the belt, causing it to deteriorate rapidly, and also increasing the belt slip.

The collar usually consists of a ring with a bore equal to the diameter of the shaft plus a small clearance, and fastened upon the shaft with a set screw whose head is countersunk. This form is shown in Fig. 10, and the accompanying table gives the dimensions for various sizes of shafts as computed by Geo. W. Childs.

Alinement of Shafting

IN the mill or machine shop, employing much line shafting, there is perhaps no one place where more power is absorbed and wasted than in poor alinement of shafting.

The difficulty of keeping the alinement correct may be due to changing the location of heavy ma-

FIG. 11. LEVELING ROD FOR SHAFTING

chinery, uneven settling of floors, uneven wear of the bearings, shafting supports becoming loose, and so forth. To look after the various details and keep

DATE _____

BEARING NO.	IN. HIGH	IN. LOW	IN. TO EAST	IN. TO WEST
1				
2				
3				
4				
5				
6				
7				
8				

INSTRUMENT USED _____

_____

OPERATOR

FIG. 12. RECORD CHART FOR SHAFT ALINEMENT

the loss of power down to the minimum, requires the closest attention and accuracy in the alinement of the shafting.

The methods adopted for establishing a line for the shafting or correcting the alinement must be worked out to suit the individual case. A method commonly employed, however, is to establish first an accurate line by the use of a stretched wire to which the line of shafting can be compared. This reference line is usually placed directly over the shaft, its level being accurately determined by means of a spirit level, and its position in regard to the machinery and building accurately measured.

Having the reference line accurately placed, and the shafting supported in its bearings, measurements are taken both horizontally and vertically from this line of reference to the shafting, and by means of the screw adjustment in the shafting supports accurate alinement can be secured. This alinement can be checked by means of a carpenter's level or leveling rods such as shown in Fig. 11, and the alinement in the horizontal plane can be checked by hanging plumb bobs from various points along the line of shafting.

In recent years the surveyor's transit or level has come into prominent use for alining shafting in mills or machine shops. By the use of this instrument and leveling rod the work of alining a shaft in the beginning, or of checking its alinement is much more rapid, and the results obtained more satisfactory than by the use of the spirit level method.

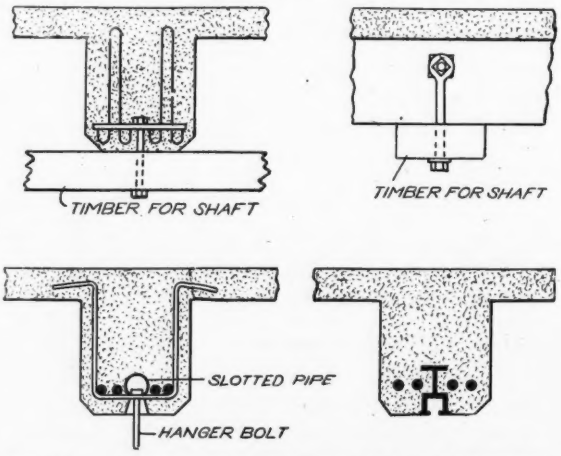


FIG. 13. METHODS OF SUPPORTING SHAFT HANGERS ON REINFORCED CONCRETE

In taking the level of a shaft with a level a straight edge should be provided which will extend from one bearing to the next and the level is applied to the straight edge. A carpenter's level is employed for this purpose, and if applied nearer one bearing, since the shafting must sag some between supports, the level will not indicate the same that it would half way between the 2 supports and thus lead to error. In testing the alinement of a shaft it is always best to keep a record, such as shown in the illustration, testing the alinement the entire length before any adjustment whatever is made in the position of the bearings, then when the test has been completed the record can be examined, which will show at a glance just which bearings must be adjusted, and how much they must be moved.

Shafting Supports

THE various appliances used for supporting shafting may be classed as overhead hangers, post hangers, or pillow blocks. The essential feature of these supports is to maintain a bearing which is perfectly rigid, presents a low frictional resistance and can be adjusted readily.

The general shape of the bearing support is triangular with the bearing in one corner. This gives

a rigid frame where it can be attached to beams, posts, piers, etc. Overhead hangers are fastened to beams in the ceiling and usually with bolts or lag screws, though the latter should be used only for light work. In modern reinforced concrete construction, special means are found necessary as boring holes in the concrete is a difficult matter after it has become set. In Fig. 13 are shown several different arrangements for supporting hangers in reinforced concrete work.

Overhead hangers should be provided with some means for removing the shafting without taking down

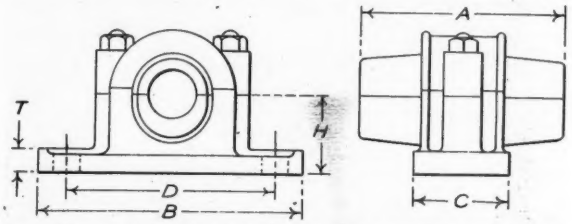


FIG. 14. RING-OILING BALL AND SOCKET PILLOW BLOCK

the entire hanger. This is accomplished in some makes by a hook shaped frame work while in others the frame work is in pieces, thus allowing the part attached directly to the bearing to be removed. In counter shaft hangers, this provision is not necessary as the shafts are usually short and can be removed by slipping them endwise through the bearing. Overhead hangers are made adjustable in the vertical direction by means of screws, wedges or the use of liners. Horizontal adjustment is made by providing oblong holes

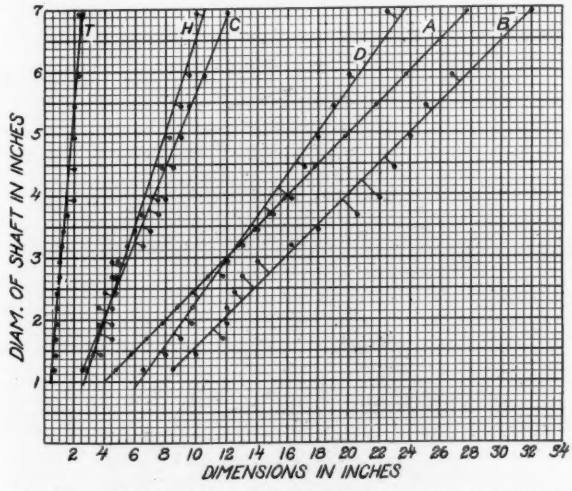


FIG. 15. PROPORTIONS OF RING-OILING BALL AND SOCKET PILLOW BLOCK

through the frame of the hanger for the supporting bolts, thus allowing the hanger to be shifted at right angles to the shaft. Some forms of hangers are fitted with ball and socket bearings which allow the bearing to rotate slightly in the horizontal plane to accommodate itself to the shaft alinement.

Wall or post hangers are fastened to the side of a wall in a similar manner to that employed for supporting the overhead hangers. These also have either rigid or ball and socket bearings and adjustment is made in a vertical direction by providing oblong holes for the supporting bolts or by means of screws, in the horizontal direction liners or screw adjustment may be employed. In this style of hanger it is quite frequent to make the bearing part of the supporting frame, lining it with some sort of bearing metal. In this case there is no need of supplying means for removing the shaft as it can be lifted out of the bearing by simply removing the upper half.

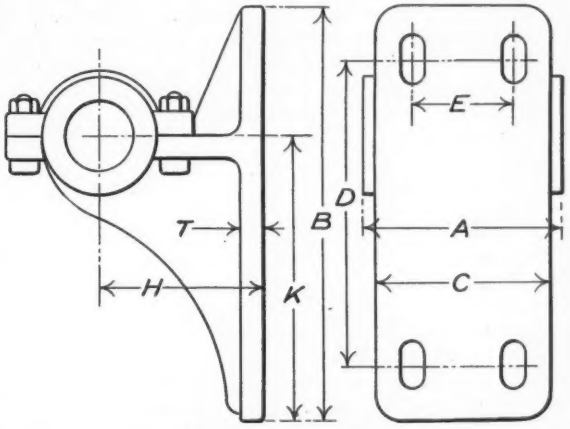


FIG. 16. SOLID POST HANGER

Pillow blocks are placed on pedestals of iron, masonry or wood and consist of the bearing with suitable means for holding it rigid and for adjusting the alinement of the shaft in both vertical and horizontal directions. Adjustment is made either by screws, wedges, liners or oblong holes for the retaining lag screws as in the other forms of shaft supports.

Proportions of various shafting supports vary widely with the styles, and ideas of manufacturers. The shaft diameter is the basis however, for calculating the bore and the other dimensions of the

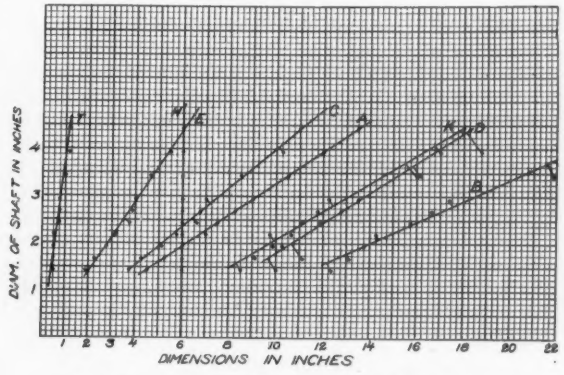


FIG. 17. PROPORTIONS OF RIGID POST HANGER

hanger. To illustrate this refer to Fig. 14 which shows a ring-oiling ball and socket pillow block made by W. A. Jones Foundry & Machine Co. The dimensional values have been used in plotting the curves in the Fig. 15 and in each case the dimension bears a certain relation to the diameter of the shafting, which is deviated from but little, in order to overcome certain difficulties in the manufacture of the article, also to keep within standard dimensions established by the maker. This relationship is particularly noticeable in regard to the length of the bearing, there being an exact ratio of 4 to 1 throughout the entire range of shaft diameters.

In like manner, a rigid post hanger, Fig. 16, is used as a typical example and dimensions for various sizes of hangers have been plotted against the shaft diameters and here also definite relations exist. The ratio of the length of bearing to the diameter of the shaft is 3 to 1, this is not so great as in the case of the ball and socket pillow block, owing to the fact that the post hanger has a solid bearing which is made shorter in order to overcome difficulties in the alinement of the shafting.

It is becoming more common to supply shaft hangers with separate bearings which are provided with ball and socket joints making them flexible to a certain extension, yet maintaining the alinement necessary for best operation. The bearings are lined with Babbitt metal and provided with means for continuously supplying lubrication in sufficient quantities.

The pressure employed on bearings varies widely with the bearing metal employed, the speed of operation and the manner of lubricating. It is customary to supply bearings which have lengths from 2 to 4 times the diameter of the shafting which has been found to give satisfactory operation. With ball and roller bearings it is necessary to employ a hard bearing surface on the shaft and in the interior of the bearing

Spacing of shaft hangers is governed principally by the deflection of the shaft which should never exceed 0.01 in. to 1 ft. of length. For ordinary line shaft work it is the usual practice to space the hangers 8 ft. on centers. This, however, varies somewhat in special cases and Tables I and II give the distance between bearings for different size shafting and special arrangement of pulleys. A heavy driving pulley should be supported on both sides by hangers and it is well in all cases to have the shaft well supported with hangers properly adjusted to give accurate alinement of the shafting.

A FEW HINTS ON TRANSMISSION MACHINERY

By Charles S. Milton

TREATMENT of the subject of Transmission Machinery in general is one of such wide scope that to give even a few hints on the whole matter would make a lengthy treatise on the subject and in the end leave the reader in a maze of useful facts, none, or but few, of which would come to his mind when the occasion for their use should arise.

For this article, the writer has, therefore, selected from among the general items of shafting, bearings, pulleys, gears, sprockets, chains, belts, etc., the subject of bearings, as being one of primary consideration.

Bearings

THE term "bearing" in the broadest sense of the word, when associated with machinery to transmit or carry power from one point to another, means without any limitations, or reservations, simply a stationary, cylindrical casing in which a shaft may revolve; such casing being stationary in so far as provision is made by lugs, or bolts, to retain it upon supports and restrain it from revolving with the shaft.

Illustrations in catalogs with such modifications in titles as: "Rigid Wick-Oiling Pillow Block," or "Rigid Ring Oiling Pillow Block," give somewhat of a more definite coloring to the above definition of a bearing, which when prefixed with a size, as 2 15/16 in. for a certain shaft, is taken by the purchaser, irrespective of other essential qualifications for the purpose intended, as being a full guarantee of reliability, whether or no the maker of whom the bearings are purchased, actually makes, or pretends to make, bearings of proper specifications in addition to those contained in his illustration and a meager descriptive title.

Mr. Inexperienced Engineer says: "Why consider any other points of specifications; I have seen the cuts in the catalogs and they all look alike for the same title?"

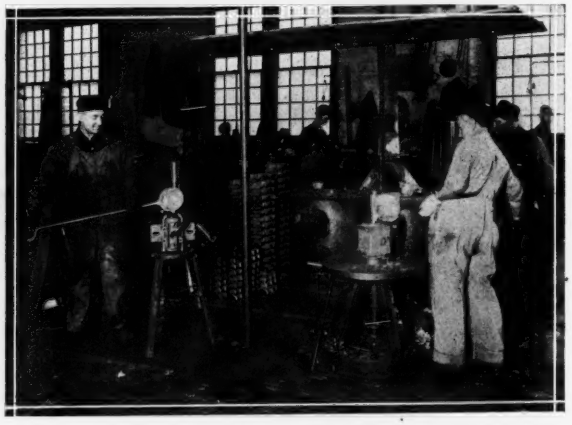


FIG. 1. BABBITTING BEARINGS AT THE JEFFREY MFG. CO.'S WORKS

Very true, they all look alike, but how about the relative strength of different makes? The length of bearings? The kind of Babbitt, together with the means and extent of lubrication? Have all these points been considered? Nine out of 10 cases, no; and in consequence, from some makes, you get your money's worth; from others, you don't.

FIG. 2. JEFFREY RIGID PILLOW BLOCK, PLAIN, EXTERIOR AND INTERIOR VIEWS

Essential Points

OF the above 3 points not generally considered by the inexperienced engineer, we will take note first of the strength of the bearing. While the general outline of a bearing may appeal to one as more artistic than another, or the paint finish on the actual delivered goods better on one than another, actual preference should be given to the pillow block with the largest, widest and thickest base, together with the heaviest ribbing up to the parting of the base and cap.

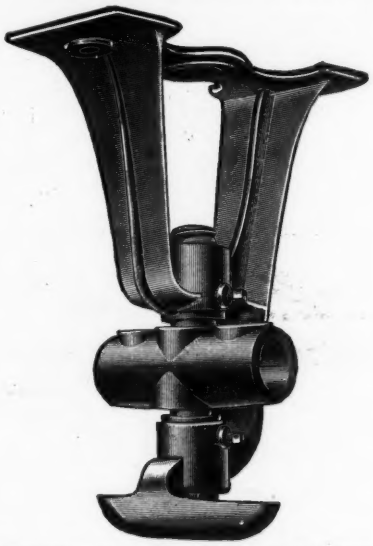
Of the cap, it should be noted that it is of ample strength relative to the base and that the cap bolts, not studs, are of ample strength to retain the cap against an upward thrust and that they are placed close up to the shaft and pass through ample lugs on the cap.

We say bolts and not studs, for should the studs break by reason of a heavy shock against the cap, they could not be as readily replaced as a bolt.

Bearing Area

ON the point of length of bearing, many makes are decidedly lacking, whereas the pressure per square inch of the projected area of the shaft in the bearing has been found in good practice to range from 400 to 800 pounds, depending upon the nature of the service to which the bearing is to be put. In general transmission this has solved itself into certain ratios of length of bearing to the diameter of the shaft. For shafts under 100 r.p.m., 2¾ times the shaft diameter should be the length of the bearing; while for 100 to 350 r.p.m. at least 3 diameters should be used. Care should, therefore, be taken to note this point when considering bearings which are being bought for their worth, lest you get a bearing which, no matter how much lubrication is used, will persist in running hot, due to too great a pressure per square inch of bearing surface.

The method still in vogue to test for the proper pouring temperature of the Babbitt is to insert a soft pine stick into the molten mass and if the stick chars readily



CALDWELL WICK-OILING DROP HANGER

the metal is hot enough. This method is as crude as the ancient method of testing for a witch, who, if she floated when cast into water and did not drown, was hauled out of the water and burned.

In connection with its Babbitt melting pots, Jeffrey Mfg. Co. uses a pyrometer, a delicate instrument for the maintaining of a constant heat under those pots, insuring a uniform quality of Babbitt in every one of the bearings manufactured. Figure 1 shows the Babbitt pots of that company and the attendants actively engaged in doing this work.

CALDWELL WICK-OILING DROP HANGERS

W. E. Caldwell & Co., Louisville, Ky.

THESE HANGERS READILY, are adjustable, vertical adjustment being obtained by means of the adjusting screws; the bearing is of the ball and socket type and Babbitted to decrease friction to the lowest point. They are self-oiling, the oil being conveyed to the shaft by means of wicking which passes from the reservoir along the shaft, thus feeding the oil the entire length of the bearing. The supply of oil can be governed by the number of strands of wicking.

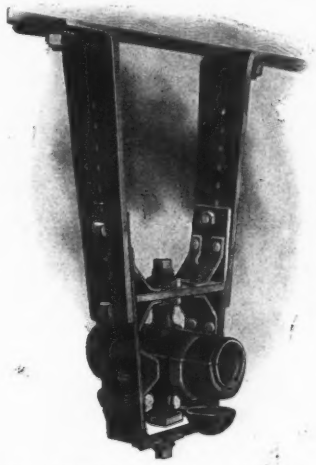
The hanger may be used either as a drop hanger or a floor stand and the bearing may be removed with the shaft without taking down the supporting frame.

LEVALLEY WROUGHT STEEL SHAFT HANGERS

Chain Belt Co., Milwaukee, Wis.

FRAMES OF THESE hangers are made of wrought steel pressed into proper form, while the hollow screw tubes or shaft adjusting screws and clamping nuts are steel castings.

By an examination of the illustration it will be seen that the steel side braces have broad base por-



LEVALLEY WROUGHT STEEL SHAFT HANGER

tions to be attached to the ceiling or the floor (when used as floor stand) with slotted bolt holes for side adjustment. Between these braces is arranged the extensible shaft support, or shaft nest, which is made in truss form and extensible along the side braces so as to afford an adjustment of from 3 to 5 in. in addition to the fine adjustment of the supporting screws above and below the shaft boxes.

The extensible adjustment is often of great advantage in uneven ceilings or variation in depth of joists, and of special service in shortening or extending the length of a hanger when desired.

The shaft boxes are Babbitted and are supported by steel adjusting tubes from beneath and above. They are hollow to admit of an oil tube passing through to the shaft when plain oiling boxes are used. A grease cup can be attached to the oil tube which is threaded for the purpose. Drip cups are suspended at the ends of the shaft box.

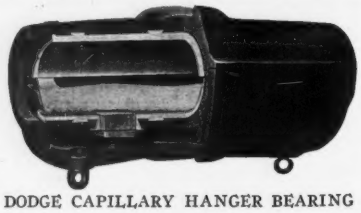
These hangers may have Babbitted ring oiling boxes or hair felt capillary oiling boxes, or plain oiling Babbitted shaft boxes.

DODGE CAPILLARY HANGER BEARING

Dodge Manufacturing Co., Mishawaka, Ind.

A DISTINCTIVE FEATURE of this bearing is the oiling arrangement which employs capillary action. Each bearing is provided with 2 oilers which consist

of a block of hard maple wood sawed lengthwise with alternate kerfs extending nearly through the block from the 2 sides, thus when compressed presenting the end grain to the shaft with V-shaped openings from the shaft to the oil well. The capillary action of this block draws the oil from the well to the shaft thus keeping the bearing oiled copiously whenever it is in action. The use of wood for these oilers is of advan-



DODGE CAPILLARY HANGER BEARING

tage in that it is not necessary to wet the surface in order to secure the capillary action necessary to draw the oil from the well as the fine pores of the maple wood are natural capillary crevices.

There is a constant general flow of oil upward and no agitation to prevent permanent settlement of heavy foreign matter in the reservoir below, thus when such foreign matter is held in suspension in the oil it settles and is prevented from going to the bearing surface.

ADJUSTABLE BALL & SOCKET HANGER

W. A. Jones Foundry & Machine Co., Chicago, Ill.

HEREWITH ARE ILLUSTRATED 2 forms of self-oiling adjustable ball and socket hangers, one being made with single brace and the other supplied with

FIG. 1. JONES SINGLE BRACE BALL AND SOCKET HANGER

FIG. 2. JONES DOUBLE BRACE HANGER

double brace. These shaft hangers are made adjustable in the vertical direction and have a small angle of play in the horizontal plane, thus making alinement of shafting an easy matter. The bearing itself is Babbitted and provided with a self oiling arrangement which requires little attention.

THE SAUER ADJUSTABLE SHAFT BEARING

Sauer Power Generating Co., Pittsburgh, Pa.

THIS IS A NEW TYPE of adjustable shaft bearing which provides means for compensating for wear and insuring a proper alinement of the shaft by using a set of bearing members or blocks adjustable in a radial direction.

The bearing consists of a casing or shell, a tapered thimble, ring and a sleeve wherein bearing members are mounted. The casing is suitably supported, and the tapered thimble and sleeve containing slots with blocks fit loosely around shaft when assembled. The bearing members mounted in the slots of the sleeve slide freely therein and are adjustable relative to running fit required, by the tapered thimble. The bear-

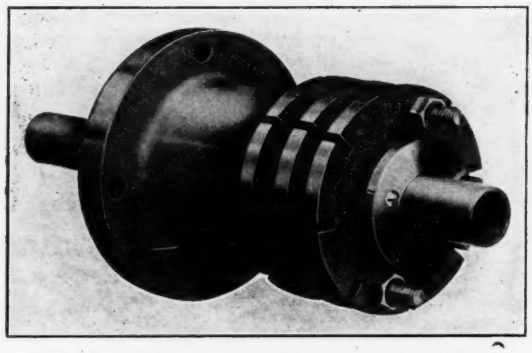


FIG. 1. SAUER ADJUSTABLE SHAFT BEARING

ing blocks are wedge shaped with their outer faces at an angle to the axis of the shaft, rounded and tapering toward the end of the casing engaging the tapered thimble, the bore of which tapers to correspond to the outer faces of the bearing members. The thimble is threaded externally and the casing internally so that the threads engage, and by rotating the former the bearing blocks are adjusted accurately to insure a proper engagement with the shaft and to compensate for wear. To turn the thimble more conveniently an annular flange B is provided at its outer end.

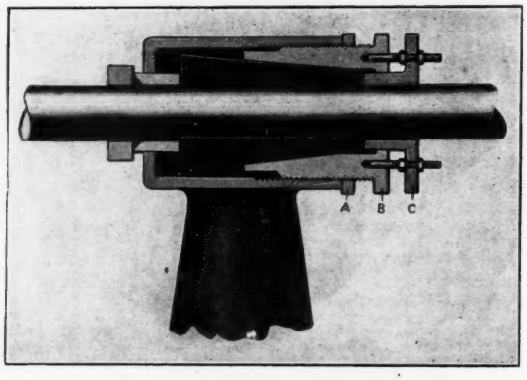


FIG. 2. SECTIONAL VIEW OF SAUER ADJUSTABLE SHAFT BEARING

In use center adjustment is assured by loosening the lock nut A and turning the tapered thimble B as running fit requires. The side motion is adjusted by tightening the nuts on the flange of the sleeve C after thimble has been set.

The side friction on bearing naturally wears only one of the bearing members at a time, by turning the sleeve on which these are mounted, it is possible to have all the blocks successively assume the position of greatest wear and thus wear them all down equally. New blocks can be inserted into the slots. It can be readily adapted and is especially suitable for high speed and accurate running machinery.

THE KINKEAD SYSTEM OF ALINING SHAFTING

Kinkead Manufacturing Co., Boston, Mass.

THE APPARATUS MANUFACTURED by the Kinkead Manufacturing Company for alining shafting consists essentially of a special architect's level built

FIG. 1. METHOD OF USING KINKEAD SHAFT ALINING OUTFIT

particularly for indoor work and capable of sighting clearly on a line of shaft 600 ft. long; a self-centering target which is hung from the shafting by a jaw clamp

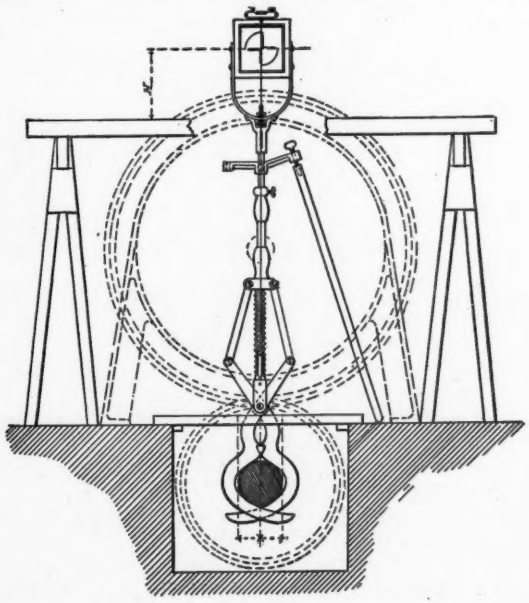


FIG. 3. USING TARGET ON SHAFT IN PIT

so constructed that it not only finds the center of the shafting, but remains invariable, irrespective of the changing size of shafting and variation due to the changing of diameter; and a fixed or stationary target used as a check to insure uniform readings and results. The portable target is capable of such arrangements and adjustment as enables the operator to work on any of the various kinds of shafting, whether overhead, in pits, on piers, under tables, and shafting with or without obstructions under or over it. The offset feature of this target enables one to work without removing any belts. The faces of the targets are transparent, and by the use of special lanterns furnished with the outfit, the work can be done as successfully at night as at day time.

Figure 1 shows the portable target as it hangs from an overhead shaft, and the ordinary method of using the outfit. Figure 2 shows a common difficulty

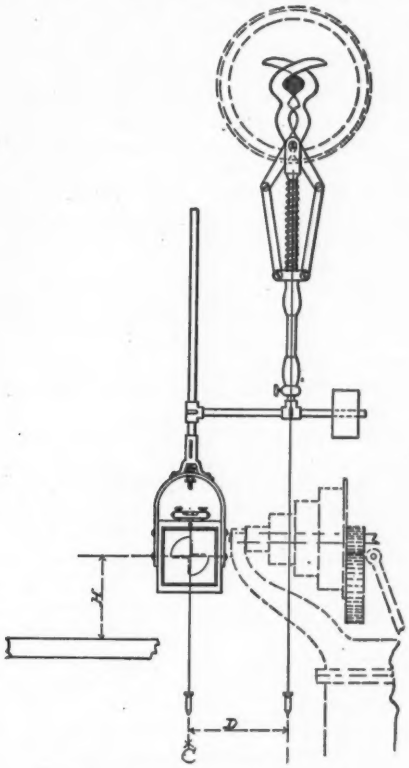


FIG. 2. USE OF OFFSET TARGET

where, owing to the location of a machine or other obstruction, it is impossible to get a sight directly beneath the shafting, so the offsetting line has to be resorted to. In this case a special offset feature is used to bring the device in plumb in the vertical position. Figure 3 shows the method of working on a shaft in a pit or beneath the floor. In this case the portable target is reversed and supported in an upright position by an adjustable leg at the side, as shown.

All the arrangements described provide for the accurate locating of both the engineer's level and the fixed target in positions convenient to the operator and by means which permit of the accurate alinement of the shafting, the alining and leveling being done at one operation.

Another peculiar feature of the tool is that when for any reason it is found that a line shaft cannot be made absolutely level without much labor and expense, the the line can be graded in, giving as good friction results, without resetting all hangers or boxes.

PROPER SIZE OF FRICTION CLUTCH MECHANISM FOR PULLEYS AND CUT-OFF COUPLINGS *

By H. J. Smith†

THE subject of choosing a friction clutch for a pulley or for a shaft coupling in many cases does not receive the attention it deserves. Much of the trouble with friction clutches arises from lack of judgment in picking the proper size clutch for the work to be done. Too often the work, which is generally of an indefinite character, and difficult to measure accurately is underestimated or understated, consequently too small a clutch is purchased. As sometimes happens a purchaser with his eyes on the low price of a small clutch, and his finger on the catalog rating, deliberately ignores all other consideration of inertia loading, speed, frequency of engagement, etc., and buys too small a clutch. Then the inevitable wear on the hard pressed friction surfaces is followed by frequent adjustments which exasperates the purchaser. In some cases where the clutch is entirely disproportioned to its work, then actual breakage of clutch parts causes the purchaser to condemn the clutch and heap contumely on the head of the clutch builder.

The horsepower transmitted by a clutch is dependent upon speed, and should always be mentioned in connection with the shaft revolutions per minute. Manufacturers of clutches have no standard method of rating, but are alike in one particular,—that the basis of rating is 100 r. p. m.

It is only in the last few years that clutches have been actually run at 100 r. p. m. and their capacity up to their breaking point measured by a prony brake. By this rational method of brake testing the clutch builder can allow a certain factor of safety, and knows by actual tests that the breaking point will be 3 or 4 times the clutch rating, and he has been governed in hitting on the precise rating for a particular clutch by figuring back from its known breaking point. This reduced capacity used as the clutch rating must also be a fairly low value when the adjustment of the wooden friction shoes is considered. If a clutch is compelled to work up to too high a rating, then too frequent adjustment of shoes becomes necessary because of the burning away of the wood friction surfaces. Stopping machinery for adjustment is not only annoying, but is often a costly matter. On the other hand if the clutch is rated low, and is large for the work, it is operated from year to year unnoticed, and with little or no cost for repairs.

The indeterminate data in the eyes of the clutch builder are the character of the work to be done, the effect on the clutch mechanism of impact at various numbers of revolutions and as to what are satisfactory periods of adjustment due to overload, high speed, or frequency of engagement and disengagement of the clutch.

There are many installations of clutches applied to particular cases where the impact of inertia loads at starting run to very high values in turning effort, and larger clutches than ordinary are advisable. For instance, the starting of flywheels, ball and tube mills, attrition mills, etc., are well known examples in which the size of clutch cannot be determined by the actual power to drive at full speed, but is actually dictated by the power required to start. It is not uncommon to find that twice the power is required to start a load than is afterwards needed to drive the load. As a general proposition the starting is always the hardest work that a clutch is subjected to. So it follows that friction clutches should be rated on their starting ability, and in choosing a clutch for a given work the starting load must be determined by actual test, estimated or dictated by experience.

As an illustration, we will suppose you want to operate some machine from your line shaft. You, naturally, therefore turn to the maker's catalog, wherein you will probably find the power to drive the machine at its normal speed, but as the maker must compete with others his estimates of the power required for his machine is likely to be low, yet at the same time he takes good care to insure driving capacity by providing a good size pulley of ample face width. According to the kind of belt, and its speed, the machine may absorb momentarily, when starting or even normally when running, more power than the listed rating of the machine. Now belting has no one absolute transmitting power, but is dependent on its tension, upon its structural strength, upon its speed and its amount of frictional contact. If the capacity of the belt is founded upon well proven values, then according to the speed, it is easy to assign horsepower values to the pulleys on which such belts run.

Engineers vary widely on the transmitting capacity of the standard double leather belt, or of 6-ply rubber belt which is practically equivalent. Nearly every catalog has different values. Of course there should be a belt horsepower table that can be taken as a standard, and Table I is offered for this purpose. Many years of trial has proven it convenient, consistent and conservative. It is based upon the following assumptions and formulae:

Horsepower of double leather belting is calculated for an arc of contact of 180 deg., centrifugal effect based on a 1-ft. strip, 1 in. square sectional area (weight 56 lb. per cubic foot) moving at V feet per minute.

T equals 90 lb. per 1 in. width of double belt ⅜ in. thick, or t.

$$\text{Then HP. equals } V\,\frac{(T-0.0000033\ t\ V^2)}{33000}.$$

The HP. values are given for pulleys up to 96 in. diam. revolving 100 r. p. m.

For ordinary speed of 2 or 3 times 100 r. p. m. these values may be multiplied accordingly without serious error, although in reality higher speeds will reduce in proportion the horsepower capacities due to the effect of increased centrifugal force throwing the belt away from the pulley face.

In the past it has been customary to select a clutch for a given pulley on the direct basis of equivalent horsepower. For instance: A 60-in. pulley with a 12-in. double leather belt, it will be seen from the table, has a capacity of 49.70 horsepower at 100 r. p. m. Formerly a clutch rated at 50 hp. at 100 r. p. m. would have been chosen irrespective of the diameter of the

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†Chief Engineer of the Hill Clutch Co.

clutch. While this choice was apparently logical, experience has shown that ordinarily a 50 hp. clutch is too small for satisfactory service. The size of clutches which are now chosen for ordinary service conditions are shown in the diagonal column. For this example a 75 hp. clutch is proper and sometimes for very severe service even a larger clutch than shown in the table should be taken.

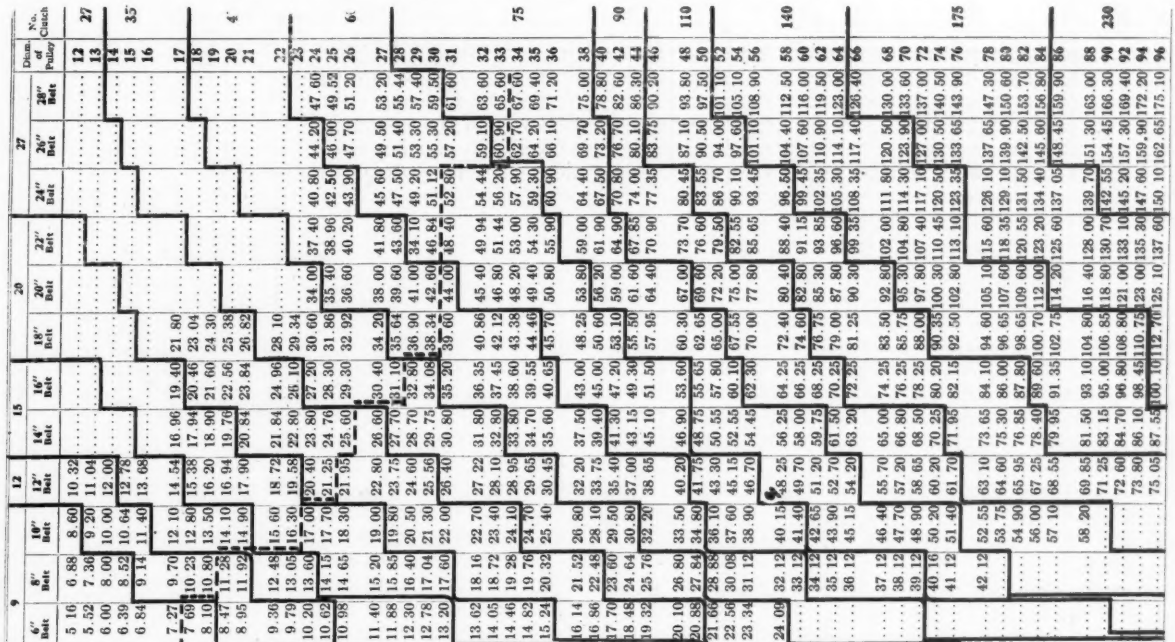
The reason for the selection of clutches for the pulleys tabulated are primarily 2.

First. A clutch must be able to start from rest its shaft or pulley, belting and driven machine. It must overcome the friction of the whole mass at rest, overcome the often tremendous inertia loads due to acceleration of that mass, and all the time while doing so must therefore be made, consequently a 75 hp. clutch will not only give better satisfaction on the 60 by 12 in. pulley, but is the logical size to use.

Second. Freedom from clutch adjustments demands a clutch amply able to start its load without wearing or burning the friction surfaces. High speed, heavy inertia starting loads and great frequency of clutch engagement, or the use of too small a clutch for the load, soon wears away the effective wood shoe surfaces. To avoid this, larger friction surfaces and a more powerful clamping action of the jaws are necessary, and these are, of course, found in a larger clutch.

Table I, in addition to its value as a power table for belts, is also a standard for the proper size of

TABLE I. HORSEPOWER OF DOUBLE LEATHER BELT ON PLAIN CLUTCH PULLEYS



Proper size of clutch for normal working conditions indicated between full heavy lines. Number of clutch also indicates horsepower capacity at 100 r.p.m. On large diameter pulleys the clutch sizes are increased be-because of starting or inertia effects.

the friction surfaces are subject to wear under the low friction of motion, which is usually about 50 per cent of the friction of rest.

If clutches were engaged at rest, and the whole mass brought up to speed at once, then the clutch would have the advantage of the friction of rest. The wood shoes would not be worn and the clutch would exert its rated horsepower capacity; and in this case a 50 hp. clutch would suffice. Such an installation is not the normal one because the clutch would then only be of use to disengage and stop a shaft or machine. As the ordinary use of the clutch is to engage as well as to disengage, allowance in its size clutch for any pulley up to 96 in. diameter, using a 4-in. to 28-in. double leather belt. The diagonal columns show the proper clutch for ordinary service conditions of these clutch pulleys.

Most of the above remarks apply equally well to shaft coupling friction clutches. In the simple case above taken the solid pulley 60 by 12 in. may be mounted on a shaft and driven by a clutch coupling, in which case the same 75 hp. clutch should be used as with the loose clutch pulley for identical reasons.

In more complex cases where several pulleys on a shaft are driven by a single clutch coupling, the clutch is properly determined by the size of shaft; although

when the size of the largest pulley is known care should be taken to see that the clutch is not smaller than the one designated in the table for that pulley.

The sizes of shafts are usually taken according to the formula, that the cube of the diameter is equal to 75 times the horsepower divided by the revolutions per minute.

Now it must not be thought that the shaft so figured will transmit a certain horsepower and no more, for there is a large factor of safety taken into account, and a homogeneous steel shaft will on occasion trans-

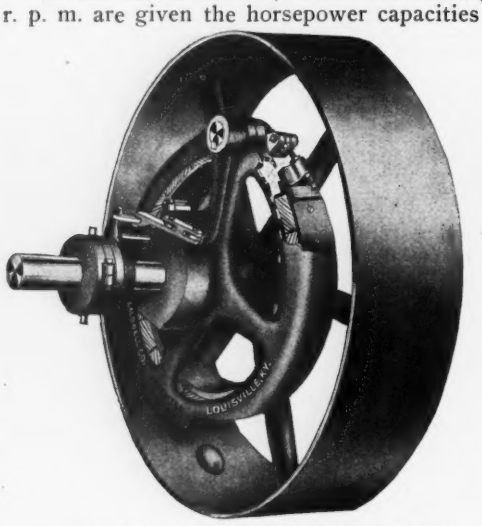
TABLE II. HORSEPOWER OF LINE SHAFTS

Diameter of Shaft in Inches	Number of Revolutions Per Minute							
	25	50	100	200	300	400	500	600
1 1/16	1.1	2.2	4.4	8.8	13.2	17.6	22.	26.4
1 1/8	1.8	3.6	7.2	14.4	21.6	28.8	36.	43.2
1 3/16	2.7	5.4	10.8	21.6	32.4	43.2	54.	64.8
2 1/16	3.7	7.4	14.8	29.6	44.4	59.2	74.	88.8
2 1/8	5.2	10.4	20.8	41.6	62.4	83.2	104.	124.8
2 3/16	6.9	13.8	27.6	55.2	82.8	110.4	138.	165.6
2 1/4	8.9	17.8	35.6	71.2	106.8	142.4	178.	213.6
3 1/16	11.3	22.6	45.2	90.4	135.6	180.8	226.	271.2
3 1/8	14.2	28.4	56.8	113.6	170.4	227.2	284.	340.8
3 3/16	21.3	42.6	85.2	170.4	255.6	340.8	426.	511.2
4 1/16	30.2	60.4	120.8	241.6	362.4	483.2	604.	724.8
4 1/8	41.6	83.2	166.4	332.8	499.2	665.6	832.	998.4
5 1/16	55.3	110.6	221.2	442.4	663.6	884.8	1106.	1327.2
5 1/8	72.	144.	288.	576.	864.	1152.	1440.	1728.

mit a far greater horsepower than given by this formula; in fact the factor of safety for the shaft exceeds that of its clutch of equivalent capacity, so in no case should the equivalent capacity of the clutch be below that of the shaft when both are figured with the same factor of 75 as a basis.

Transmission manufacturers ordinarily make no consistent equivalent shaft determination for their clutch couplings, so there is no settled standard. Still as in the above clutch pulley table, and with the same rating of clutches, the following table of horsepower capacities has been thoroughly tested out, and is offered as a standard table of transmission shaft capacities.

In the fourth column, under the heading of 100 r. p. m. are given the horsepower capacities of shaft-



CALDWELL FRICTION CLUTCH PULLEY

ing which match identically with the capacities of the clutches, strong enough under normal service conditions for their respective shafts. From this column are taken the equivalent shaft values for friction clutch cutoff couplings.

CALDWELL FRICTION CLUTCH PULLEY

W. E. Caldwell Co., Louisville, Ky.

IN THE CONSTRUCTION of the Caldwell clutch the prony brake principle is made use of. The friction wheel is mounted rigidly upon the pulley, while the brake is attached through arms to the driving shaft. Tightening the brake is done by means of a toggle joint lever; this gives the brake even pressure on the entire circumference of the friction wheel. The brake band is lined with blocks of hard wood placed with the ends of the grain to the friction surface and adjustment is made by means of one screw which varies the circumference of the brake band.

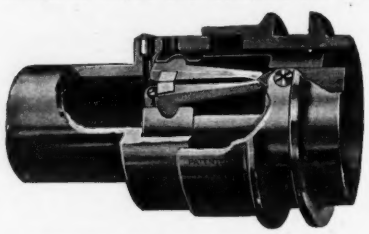
These clutches are adaptable for use on pulleys, sprocket wheels, gear wheels and shaft cutoff couplings.

JOHNSON FRICTION CLUTCH

Carlyle Johnson Machine Co., Manchester, Conn.

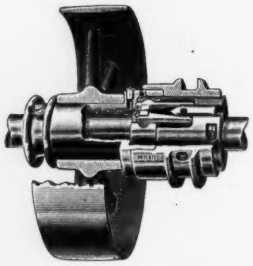
IN THE TRANSMISSION of power in machine shops and factories, the possibilities are unlimited in the way of drives, with which a small, compact, friction clutch can be used. The accompanying illustrations show the Johnson friction clutch.

These clutches meet the demand for a small fric-

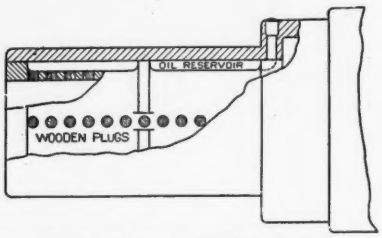


INTERIOR OF SINGLE CLUTCH

tion drive, occupying a small space. The figures show the smooth exterior of the single clutch, with no projecting parts, and as all the working parts are enclosed they are kept free from dirt. Two views show the interior of the single clutch which consists of a body fastened to the shaft carrying a split ring in which is inserted a pair of levers. A curve-shaped wedge, which is made part of a shipper sleeve, forces



APPLICATION OF JOHNSON CLUTCH TO PULLEY



SELF-OILING CLUTCH BEARING

the levers apart, expanding the ring, bringing its outer surface into frictional contact with the inner surface of the friction cup, which is formed at the end of a sleeve and on which can be mounted either a solid or split pulley, as shown, or cones or gears.

The leverage is compounded so that it requires but little pressure on the shipper handle to operate the clutch. Adjustment is made by means of a collar-screw screwed into the base of one of the levers, and is easily reached by a screw-driver through a hole in the edge of the friction cup. This collar screw shifts

2 hardened tool steel fulcrum blocks also in the base of the levers. These blocks are tapered, as well as the recesses into which they are fitted, and when forced down by means of the collar screw, force the levers further apart at the fulcrum point, thus giving a greater expansion of the friction ring.

These clutches are also made double, which makes them applicable for 2 speeds, or for forward and reverse motion, attained by crossing the driving belts or by back gearing.

A new feature of these clutches for line shafts is the driving collar. This collar is doweled to the clutch body and fastened to the shaft by means of 2 binder bushings, obviating the necessity of cutting keyways in the shaft, and admits of moving the clutch to any desired position on the shaft.

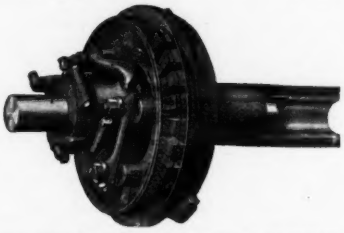
A special oil arrangement is also shown. A cast-iron or bronze bushing, chambered out on its exterior diameter, is forced into a clutch hub, bored out large to receive it. Rows of small holes are drilled through this bushing from these chambers to the shaft bore, beforehand, and these holes are plugged with small wood plugs, cut lengthwise of the grain, and a kind of wood is used that is quite porous. The oil chamber formed by forcing this bushing into the clutch hub feeds oil constantly to the shaft bearing through these small wood plugs.

DODGE SPLIT FRICTION CLUTCH

Dodge Manufacturing Co., Mishawaka, Ind.

THIS IS DESIGNED especially for high speed and hard service. Being split, it is applicable to the shaft without interfering with the balance of the equipment, thus facilitating repairs and renewals. Adjustment is easily made by tightening the clamp nuts of the draw bolts passing through the levers.

The principal feature of the clutch is its frictional power which is obtained through an outside disk into which are driven hard maple blocks presenting end grain, and an inside driving plate which is keyed to the shafting and the outside driving plate attached to the inside driving plate and levers. By the movement



PHANTOM VIEW OF DODGE CLUTCH

of the levers the driving plates are brought into contact with the wooden blocks, thus transmitting power to the sleeve or hub of the coupling. The clutch is operated by a hand lever or a geared shifter attached to the collar which slides upon the shaft. The levers which operate the friction device fit into holes in this collar and when in engagement hold the collar in place upon the shaft.

Another prominent feature of the Dodge clutch is interchangeability of the sleeve for carrying pulley, sheave, gear, sprocket, etc., with the hub which makes it a cut off coupling. This is accomplished by a standard bolt circle in the mechanism corresponding to the bolt circles in the flanges of sleeves and hubs for all shaft sizes within the range of the clutch. This clutch does not require pulleys, gears, etc., of special design. These connections of regular pattern are attached to sleeves just as they are fastened to the shaft.

THE HILL CLUTCH COMPANY TRANSMISSION MACHINERY

The Hill Clutch Co., Cleveland, Ohio

THIS COMPANY OPERATES its own shafting mill, the product of which is a high grade of turned steel shafting, especially prepared for power transmission purposes. The bars are of high elastic limit, and have high transverse and torsional strength. These qualities permit the shafting to withstand heavy stresses and strain without permanent distortion. Turned steel being homogeneous throughout has no hard outer skin which when penetrated often causes shafting made by other processes to kink.

Collar Oiling Bearings

PROBABLY the most important feature of any line shaft equipment is the bearings. In the Hill Collar Oiling bearing a fixed collar is employed. Oil stored in large reservoirs in the bottom of bearing is continuously and positively elevated to the top reservoirs by the means of the heavy split collar clamped to the shaft. From the upper reservoirs it flows by gravity over the entire bearing surface. The bottom reservoirs are provided with partitions which insure settlement of any dirt or grit, and the oil can be drained off by removal of screw plugs. A few revolutions of the shaft, and the bearings are flooded.

It is not only by the positive and copious means of oiling that the collar oiling bearing gains in efficiency, for the collar also serves as a thrust collar, and operates in a bath of oil and thrusts against Babbitted seats. For this reason, no outside collars are required unless the end thrust is extremely severe.

The design of the Hill drop hanger is such that the entire weight of shafting, pulleys, etc. is carried directly by the hanger frame, without depending upon bolts holding the yoke in position.

The bearings are supported by trunnions allowing a ball and socket movement. This, combined with a 4-point adjustment, which is vertical as well as horizontal,

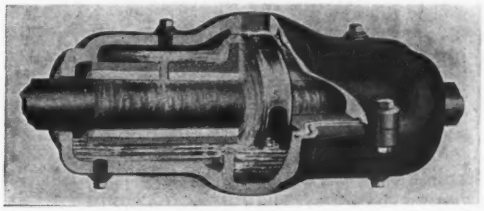


FIG. 1. HILL COLLAR OILING BEARING

is of great convenience when erecting or re-aligning shafting.

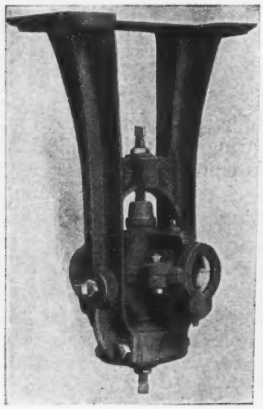
The Hill ball and socket bearings allow the transverse adjustment within its mounting. Their ease of transverse adjustment of a line of shafting by moving the bearings instead of the hanger frames is of vital importance at the time of erection, or thereafter.

Friction Clutches

IN THE distribution of power by line shafting great economy can be obtained in providing for flexibility by the use of friction clutch cut off couplings and pulleys. Each department, line or shaft or individual machine may be controlled independently of the balance of the equipment. There results a great saving in power and expense by being able to cut out at will sections of a

shop or non-producing machinery. And in the case of accident instant control is secured by means of clutches when otherwise considerable time might be required to shut down the prime mover.

The Smith type of Hill clutches are built with 3, 4 and 6 arms according to their capacity. The friction surfaces are wood against iron, which is a combination offering great frictional resistance, and the shoe area is exceptionally large. The coefficient of friction is the same at all points, owing to the heavy cast-iron jaws, rigid guides, and the balanced toggle action through which the pressure is applied. The action of the clutch mechanism is positive, no springs being used in the



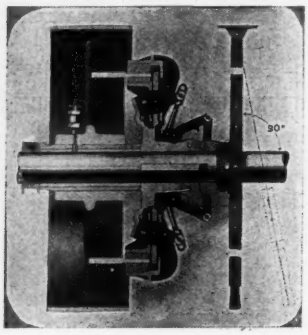


FIG. 2. THE HILL DROP HANGER
FIG. 3. HILL CLUTCH, SECTIONAL VIEW

construction. The sectional view shows the toggle connection from the cone to the jaws, which positively releases, as well as engages the friction surfaces. All of the toggle mechanism is of steel or forgings, with the single exception of the levers, which are of cast iron.

Another noteworthy feature in the design of this clutch is that any working part, including the inside jaws, may be removed parallel to the shaft from the mechanism side. This can be done without disturbing the main spider casting or pulley, as bolted gib guides secure the inner and outer jaws to the spider as shown in the illustration. The entire clutch mechanism is open and accessible for adjustment and the removal of shoes when necessary. The clutch pulleys are mounted upon split removable sleeves, Babbitted or bronze lined as specified, which can readily be replaced without disturbing the pulley or clutch.

Another important feature of this clutch is the self-centering mechanism. As all jaws fulcrum at points equidistant from the center of the shaft, they form a centering or shaft alining device without the necessity of troublesome shaft bushings.

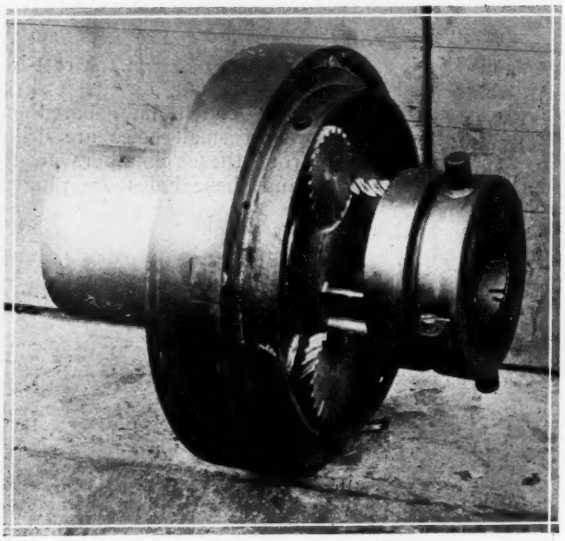
The clutches are built in either solid or split types. In the split construction, the bolting lugs are so distributed as to offer the greatest resistance to the forces tending to part the clutch. These clutches are built in 19 sizes, ranging in capacity from 9 to 1300 hp. at 100 r. p. m.

THE HILLIARD & RICHARDS FRICTION CLUTCH

Hilliard Clutch & Machinery Co., Elmira, N. Y.

THE 2 FRICTION PLATES in this clutch are drawn against the friction ring, which contains a number of hardwood inserts, by screws that are operated by spiral gears and turned by spiral racks attached to a sliding collar. Some of the advantages claimed for this clutch which has reecntly been put on the market are that the screws can be turned very slowly, the tightening or loosening of the operating mechanism is not affected by centrifugal force, adjustments are easily made and the interior is kept free from dust. By turning the screws slowly when desired the friction is gradually applied to the load, picked up smoothly and without any sudden jerk.

Owing to the fact that centrifugal force does not affect the operating mechanism this clutch is particularly adapted for use on high speed lines or counter shafts. When adjustment becomes necessary, owing to the wear of the wood inserts, it is accomplished by



HILLIARD & RICHARDS FRICTION CLUTCH

removing the nut which locks the sliding collar in position. The collar may then be drawn out and the spiral racks taken out of mesh with the gears, each gear is then turned the same number of teeth to the right which draws the friction plate up the same amount on all sides and the racks can again be placed in mesh with the gears which gives an adjustment with uniform pressure throughout the friction surfaces. Ball thrust bearings are provided for the spiral gears to reduce the effort necessary to engage the clutch.

The clutch sleeves are furnished bored and reamed and Babbitted or bronze bushed. In all the different styles there is an oil reservoir, bored out in the center, having suitable grooves for distributing oil.

The cut shows a 20 in. clutch which drives from a 250 hp. compound engine in a large brick yard. These clutches are particularly adapted for cement mills, glass factories, paper mills, rolling mills or any place where there is any severe usage for clutches.

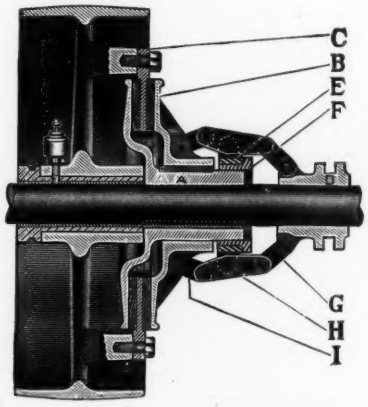
THE PLAMONDON DISK TYPE FRICTION CLUTCH

A. Plamondon Manufacturing Co., Chicago, Ill.

USE IS MADE in this clutch of 2 friction disks, A and B, which are solid, thereby making the friction surfaces absolutely dustproof, and the adjustment of these plates for wear on the friction plate C is made entirely by means of one adjusting nut, giving a uniform pressure on all parts of the friction surfaces.

The friction plate C is lined on both sides with continuous hard maple segments, and is made in halves

so it can be removed for relining without disturbing other parts of the clutch. The general design is such that no part of the clutch is affected by centrifugal action, and therefore, when in operation or disengaged, the clutch will remain in the desired position. In operation, the disks A and B are pressed against the friction plate C by means of the toggles G, H and I, by moderate pressure on the sliding collar D. The pressure developed through the double toggles is such that the larger sizes of clutches are readily engaged and disengaged by means of hand levers without the use of geared mechanism.



SECTIONAL VIEW OF PLAMONDON FRICTION CLUTCH

The clutch shown in the illustration is of the solid type. It can also be made in halves, that is split, when necessary to avoid taking down a line shaft, but the maker does not advise using them in this way unless absolutely necessary; as it requires double the number of parts and the use of bolts which should be avoided when possible in the use of friction clutches. The clutch is adapted to high speed, being installed in a number of plants where the speed is 1000 r.p.m., and owing to the dustproof qualities has given excellent service in Portland cement works.

RELATION OF POWER TRANSMISSION AND BABBITT METAL

By F. Jordan

IN figuring on the problems in connection with power transmission no economical plan can well be carried out unless careful consideration is given to the character and quality of the Babbitt metal used in the bearings, as a means of minimizing the loss of power due to frictional resistance. The first and most vital matter to decide is whether or not it is wise to use a cheap or ordinary grade of Babbitt metal because of the initial saving in cost—or whether it is preferable to apply a high grade antifriction metal to all of the bearings in a plant.

It is true that some bearings are less trying on a metal than other bearings and for that reason it is often thought that any cheap grade of metal is good enough for such bearings, but is it true economy to do this? The cost of the Babbitt metal itself used in an ordinary size bearing is usually inappreciable as compared with the cost of labor in applying it. The frictional resistance from the use of a low or ordinary grade metal is waste of power that is reflected back to the boiler in causing a greater consumption of fuel. Such bearings are also liable to run hot and have to be kept flooded with oil and the wear on the shaft and the bearing is much more rapid. It is doubtful if these low grade metals have any economic value to the consumer of Babbitt.

This matter has been thrashed out time and again by large manufacturing plants who have found great economy in the use of high grade metals: effecting in some instances a saving of 33 1/3 per cent in fuel, 75 per cent in the consumption of metal and 60 per cent in oil. Of course, such high percentages could not be expected in every case, but are symptomatic as showing the possible savings to be effected by the use of a high grade antifriction metal. Experience has shown that these same bearings lined with high grade metals will usually run from 10 to 20 times as long as the ordinary grades and thereby reduce the cost for labor in rebabbitting to an extent that amounts to a considerable item in some plants; there is also to be considered a reduction in the liability of shut downs.

It is generally known to the mechanical world that certain high grade bearing metals give better services than the ordinary grades, but they do not always know the reason why. It is only within comparatively recent years that scientists have discovered that Babbitt alloys made from metals containing impurities of low atomic value will cause greater frictional resistance and consequent heat and wear, than will a similar alloy made from high grade virgin materials and where such metals are still further purified by chemical treatment and graphite incorporated into the mass, as is sometimes done, it naturally follows that the lowest coefficient of friction is obtained with the correlated reduction in frictional resistance and increase in length of service.

Of course, the manner in which a Babbitt metal is applied is an essential factor in the results to be obtained —this, however, involves no difficulties whatever, as the directions for using Babbitt metals are exceedingly simple and are based upon common sense reasons. There are really only 2 important rules to observe in pouring a Babbitt metal:

First—Have all your preparations ready and pour metal as soon as it is hot enough to char a white pine stick. Originally, when this rule was made it was thought that the metal was injured by overheating and it is true that superheating any metal does impair its vitality, but as a matter of fact it was only recently that it was discovered that if a white metal alloy was left in a highly fluid state for too long a time the various ingredients of which it was composed would separate, the lead being the heaviest would gradually settle on the bottom and the tin and antimony would work to the top and a bearing poured in that condition would have soft spots (lead) and hard spots (antimony). As a Babbitt metal is a mechanical mixture, it is important that it should be poured in a homogenous condition.

The next rule is to heat the box and mandrel. If a metal is poured into a cold box and around a cold mandrel it will check its free flow and produce a poor casting. A cold mandrel produces a thin chill on the face of a bearing and as this chill does not adhere very tenaciously to its comparatively soft backing it will be torn loose by the grinding force of shaft and slough out of the box. Heating the mandrel also burns off any grease or moisture that is liable to be deposited upon the mandrel by finger prints or from other sources and if allowed to remain upon the mandrel they will expand into gas when covered by the hot metal and this gas will hold back the metal and cause a blow hole in face of bearing. The low grades of metals are liable to contain ingredients that produce blow holes no matter what precautions are taken to prevent.

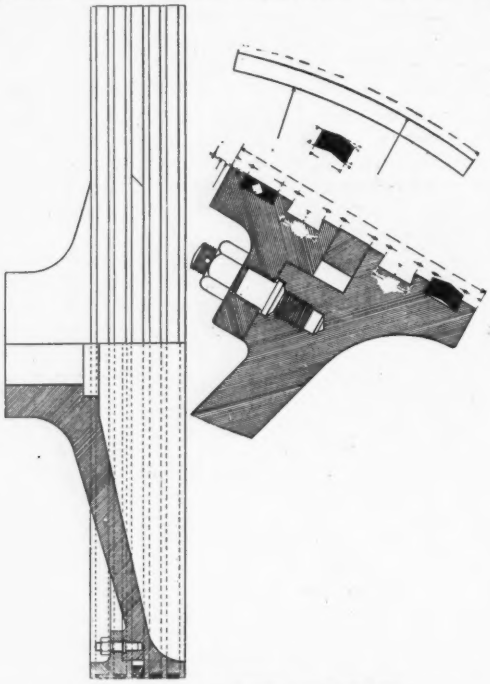
These 2 simple rules cover practically all the law and directions for Babbitt pouring. There are several other points of minor importance to be observed. If possible, a metal should be peened before it cools off, as a hot metal yields more readily to the blows of a hammer and there is no danger of ever cracking it. Any oxide or scum should be held back and not allowed to enter the box. When a metal begins to change from a silvery to a yellowish tinge indicates the best time to check the heat.

The lack of proper knowledge of these simple rules has frequently resulted in a good metal being condemned or failure to secure maximum results. The importance of reducing frictional resistance as a means of gaining an increase of power is obvious. It will often save the necessity of overloading the boiler besides the other advantages and economies pointed out. This subject is well worth the careful consideration of every user of Babbitt metal.

ALLAN METAL

A. Allan & Son, New York, N. Y.

THIS IS AN ANTIFRICTION metal, an alloy of copper and lead which the maker claims possesses exceptional wearing and antifrictional qualities. The illustration shows how pistons are constructed for Allan metal, an application which has gained much favor with engine builders and engineers. Dovetailed grooves are cut around piston or bull ring and should be ½ in. deep. Width of grooves at face of the piston from 1 to 2 in. Stock



ALLAN METAL USED ON PISTONS

between grooves ¾ in. The rings of Allan metal are supplied cast in segments and are peened or hammered down until the metal is forced into the grooves and locked by the splay. It is reasonable to suppose that an antifriction metal with a high fusing point should reduce wear and friction on the cylinder wall and prevent scoring.

This metal is also used for filling bearings, metallic piston rod and valve stem packings and as globe valve disks. Owing to its high fusing point this metal cannot be melted in a ladle like white Babbitt, but must be run down in a graphite crucible like brass. Allan metal is cast or poured into the bearings by a method similar to that used in ordinary Babbitting, where the appliances for melting at a high fusing point are at hand. Another method of applying Allan metal to bearings is semicircular slabs, strips, buttons, etc., which are peened into the cavity of the bearing and bored to size.

MAGNOLIA METAL

Magnolia Metal Co., New York

IF A BABBITT METAL squashes out of a bearing it does not necessarily follow that the metal is too soft and it is well to remember the following facts.

Few machines are so constructed that the weight of the shaft in itself will cause the bearings to squash.

Unless the shaft is out of alinement or the metal has been poured in a separated condition, a Babbitt will rarely or never squash out of the bearing unless it becomes hot.

Babbitt metals generally fuse at 450 to 500 F. and no matter what degree of hardness they may possess, if the heat of the bearing reaches around 300 F., from either frictional or initial heat, it will soften and squash.

Babbitt metals are hard or soft in proportion to the quantity of antimony and copper used, and these metals, if used to excess, detract from rather than help the antifrictional qualities of an alloy; they also add greatly to its brittleness and impair its value in other ways.

There is therefore a happy medium to be observed between the 2 extremes of hardness and softness.

It has been demonstrated by scientific investigation and confirmed by every day practical tests, that alloys made from inferior grades of metals such as scrap or antimonial lead create greater frictional resistance and wear faster than will the same composition made of high grade virgin materials, because these low grade metals contain impurities of low atomic value that cannot be eliminated. Regarding the hardness of metals, take as an example a white brass which is principally a mixture of tin and speltzer (zinc). This is one of the toughest and hardest of all the white metal alloys, but because of its poor antifrictional qualities, it heats quickly and when hot it has the peculiar quality of losing all atomic cohesion and it can then be scraped off with a stick or pulverized by a light blow and becomes like putty.

You can see from the foregoing that the success of a bearing depends not so much upon its great hardness and ductility as it does upon its antifrictional qualities.

The fusing point of Magnolia Metal is about 500 deg. F. and it will withstand great compression test, and yet it is not so hard that it will not adjust itself to any inequalities of the shaft and permit of the blows of the peening hammer without cracking.

It is composed of virgin materials further purified by a special foundry process; it contains ingredients that add to its free flowing qualities and minimizes shrinkage and then graphite is incorporated.

It is a matter of common knowledge that Magnolia Metal possesses the quality of filling in and smoothing down the irregularities of the shaft and bearing, imparting to both a finish like polished steel. Elaborate tests by governments and scientists show that Magnolia Metal possesses a low coefficient of friction

and it is difficult to run the heat of a Magnolia lined bearing up to a destructive point. Some tests of this have been made showing little rise in temperature where only water was used as a lubricant and also without any lubrication.

A bearing metal that heats quickly will wear rapidly because of the frictional resistance and is wasteful in every other way.

REDUCING FRICTION ON LINE SHAFTING

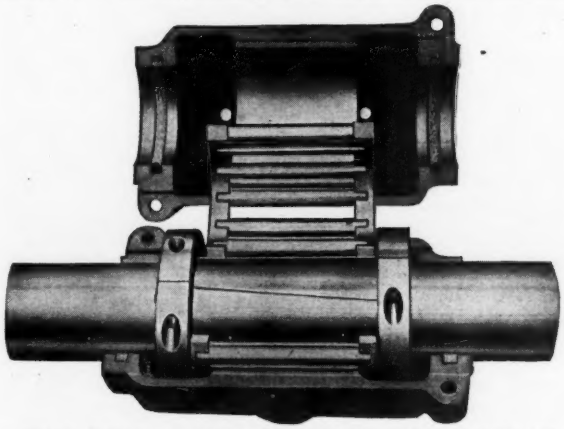
By John A. Schroeder

IT IS A well-known fact that has been proved many times, that the mere turning of the wheels consumes from 25 to 50 per cent of the total power generated, and in fact, in factories employing a great deal of heavy machinery, such as in rolling mills, etc., this has been found to run up to 75 per cent in many cases and even in extreme cases as high as 90 per cent.

Much of this frictional resistance has been traced directly to the line shafting; so much of it in fact that many manufacturers endeavored a few years ago to discard line shafting altogether by installing individual motors for each machine. It soon developed, however, that except in cases where machines were run intermittently, or where each machine required quite an amount of power, the low efficiency of small motors together with the high cost of a number of them, with wiring, starting devices, etc., resulted in little saving, if any, by discarding the line shaft drive for the individual motor.

A most economical transmission of power is through what is termed the group drive, or a number of machines operated by one motor through the agency or the line shaft, especially if roller bearing shaft boxes are used.

One of these roller bearing shaft boxes, the Sells, made by the Royersford Foundry and Machine Co., is universal in adaptation; that is, any bearing of a given size can be fitted to any hanger, post hanger or pillow block of a corresponding size, either for new installation or substituting where the regular plain or ring oiling bearings are now in use.

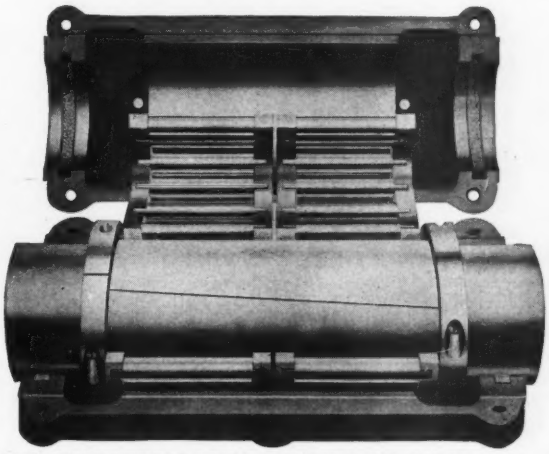


SELLS ROLLER BEARING OPENED TO SHOW DETAILS OF CONSTRUCTION

As will be seen by the illustration they are split throughout, making it easy to install them without the necessity of moving hanger frames or anything on the shaft. All parts are made interchangeable, so that in case any part of the bearing should become mislaid or broken, it can be replaced without the necessity of replacing the whole box.

Instead of allowing the rolls to run loose in the box, the Sells has a self-contained roller structure, a split steel cage which holds the case hardened steel rolls equally separated from each other. This eliminates all the friction caused in the old style box where the rolls revolve against each other, and also insures that the rolls will revolve parallel with one another and not diagonally with the box.

To prevent the shaft from being cut and scored by the case hardened steel rolls, this bearing is fitted with a hard steel bushing, clamped on the shaft by 2 split collars. In order to increase the adaptability of the Sells and to broaden its scope of usefulness, it is constructed so that these bushings can be varied in thickness to fit the bearings to different diameters of shafts. This enables the user to change his shaft or adopt it to different bores as he desires. Each roller structure is susceptible to 3 such change of bushings.



THE SELLS DOUBLE ROLLER BEARING FOR LARGE HEAD AND JACK SHAFTS

The steel split collars which clamp this bushing to the shaft also perform another important duty. Being fast to the shaft they rotate at a speed 3 times as great as that of the roller structure itself, and therefore provide a rotating surface for the ends of this roller structure to run against, aiding the latter considerably. As the illustrations show, all end thrust friction is eliminated by the full floating type construction.

The 2 halves of the Sells bearings are fitted together by milled joints in order to make them dust proof, and to further insure this the manufacturers use a heavy felt wiper at each end of the box which also serves the purpose of preventing oil from running out of the box. The box is also fitted with drain holes so that it may be flushed with kerosene oil or other cleansing fluid when the oil thickens or gums. Tapped holes on the top of the box provide for oil cups.

For head shaft or jack shaft purposes 3 11/16 in. or larger, a double roller structure is used so as to provide a longer and more suitable bearing surface for these heavily loaded shafts.

The manufacturers sell these bearings on a guarantee that they will reduce the friction load from 25 to 50 per cent.

SOURCES AND METHODS OF PRODUCTION OF LUBRICATING OILS

By W. A. Converse*

SINCE MUCH IS BEING SAID in this issue regarding the best and most suitabout lubricants for the several different classes of service, the writer feels that in order that as much information as possible may be transmitted to the reader some knowledge of the source of of these products, together with a citation of the differences in the different types of crude petroleum methods of distillation and refining, would be not only essential but opportune at this time. Therefore the writer in this article will endeavor to furnish some of such information or knowledge, feeling that most users of lubricants are not conversant with the greater portion of them; consequently, we will start with the original crude material,—petroleum.

Petroleum

WITHIN the memory of comparatively young men, petroleum, from being a medicinal curiosity, has advanced to be an almost indispensable article of consumption; and from a few barrels, which, in 1859, were collected by slow and painful processes, the annual production has increased to many millions of barrels, and is still increasing. It may safely be said that no other branch of commerce has ever in so short a time attained such enormous proportions.

Fifty years ago the value of petroleum was unrecognized, and the vast sources from which it was to be derived, although separated from us only by a thin crust of rock and soil, were unsuspected. With careless and unsuspecting feet we traveled over hidden treasures more valuable and wonderful than the gold mines of California. Now the extraction, refining and transportation of petroleum forms a branch of industry involving the employment of vast amounts of capital and thousands of busy hands.

Inventive brains were at first set at work and stimulated to contrive appropriate apparatus for furnishing by it the most economical and beautiful light. Ships, rendered no longer necessary for chasing the whale, by the introduction of an oil cheaper and more valuable than whale oil, have been freighted with the rival oil, and sent with it to the markets of the world. All this has happened since 1859.

In 1833 Prof. Benjamin Silliman described, in the American Journal of Science, the oil spring of the Seneca Indians, near Cuba, New York. The decade from 1840 to 1850 was remarkable for the number of travelers who, in different parts of the world, noticed the occurrence of bitumen, and also for several elaborate researches upon the geological occurrence and chemical constitution of its different varieties. Travelers visited the far East, and even China, and gave descriptions of the naphtha springs of Persia, the fire-worshipers of Baku, and the fire-wells of China.

In this country Percival, in Connecticut, and Beck, in New York, called attention to the fact that bitumen was of frequent occurrence in thin veins traversing the metamorphic and eruptive rocks of Connecticut, New York and New Jersey.

Notwithstanding its wide geological distribution, petroleum is obtained only in few countries to such an extent as to form the basis of a flourishing industry, the United States of America standing in the front rank in this respect. Of great importance also are the oil regions of the Caucasus (Baku) and of Galicion. Considerable quantities of oil are also obtained in Roumania as well as in Germany (Alsace).

The existence of petroleum in North America was mentioned in a letter written as early as 1629 by a Franciscan missionary. In 1750 a French Commander at Fort Duquesne gave a description of certain petroleum springs in a letter written by him to General Montcalm; and later frequent mention is made of these springs in correspondence relating to territory which is now known as western Pennsylvania, Ohio, West Virginia and Kentucky.

In the year 1829 a well drilled for brine in Cumberland County, Kentucky, produced such a flow of oil that it was regarded as a natural phenomenon during the 30 years following. It is estimated that the total flow amounted to 50,000 barrels, the greater portion of which went to waste, much of that which was saved being bottled and sold as a cure-all, to be used both externally and internally.

Early Use.

THE first investigations pertaining to the composition of petroleum and the uses that it or the products therefrom could be put to, were made about 1847, by an Englishman by the name of Binney; and a few years following, he, together with James Young and others, commenced the manufacture of illuminating and other oils, the success of this venture being so pronounced that it soon attracted attention in the United States, and in 1851, at which time the crude oil was worth 75 cents a gallon, an investigation was started by 2 men named Atwood and Merrill at the works of the U. S. Chemical Manufacturing Co.'s plant at Waltham, Mass.

The object of this investigation was simply to confirm the work of Binney and further ascertain the value of petroleum as a source of illuminating oils, which was at this time fully established, but on account of the scarcity and high price of the crude, its application commercially was prevented.

Origin

OPINIONS of scientists, geologists and chemists regarding the origin of petroleum, and the bitumens related to it, differ very much, not taking into consideration the views of many laymen. Of the latter only one, that of a Pennsylvania "oil man," may be mentioned on account of its originality, according to which the American petroleum is the urine of whale which has found its way from the polar circle through subterranean passages to Pennsylvania. It would not be possible at this time to go into all the theories that have thus far been advanced, covering the origin and process of formation of this substance, but following a resume of the theories advanced, we arrive at virtually the following conclusions:

*Chemical Director, Dearborn Drug and Chemical Works, Chicago, Ill.

First, petroleum is of animal origin; saurians, fishes, cuttle fishes, coralloid animals, etc., especially, have authentically contributed to its formation, though soft animals without solid frame, of which no authentic, determinable remains are left behind, may also have co-operated.

Second, while coal has been formed by the transformation of vegetable substances, petroleum and the allied bitumens, it is believed, originated from animal substances.

Whether petroleum could be formed from animal remains only under special conditions, is an unsolved problem; neither is the nature of these conditions known. One investigator has, however, recently come out with the statement that he has produced from animal substance an oil corresponding to heavy petroleum.

Third, petroleum has been formed in all ages of the earth's history of which animal remains exist.

Fourth, the formation of petroleum has been effected without the co-operation of an uncommonly high temperature.

Fifth, it has taken place under higher pressure, the influence of which upon the chemical process is unknown.

(To be continued.)

ALBANY GREASE AND GREASE CUPS

Adam Cook's Sons, New York City

THE HARD, MEDIUM AND SOFT consistencies of Albany Grease yield to the engineer provision against wear and injury to the journals of any type

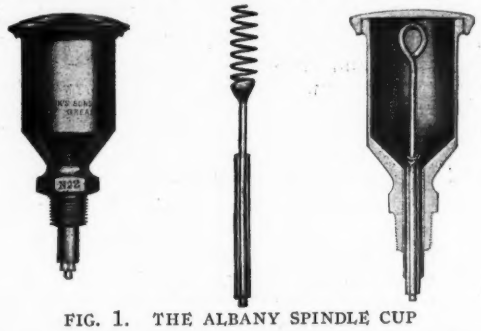


FIG. 1. THE ALBANY SPINDLE CUP

of machine. Elimination of waste is complete because the grease feeds only while the machine is in motion. If the soft consistencies are used at cold temperatures

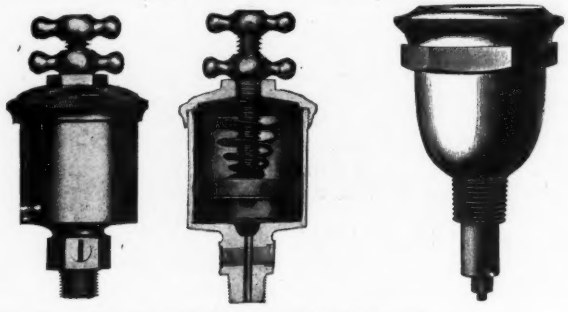


FIG. 2. ALBANY SPRING COMPRESSION CUP

FIG. 5. ALBANY LOOSE PULLEY CUP

and the hard consistencies at hot temperatures, every engineer will find Albany Grease a sanitary and economical lubricant.

Although Albany Grease may be applied in any type of cup, the above company has designed several types particularly adapted for its use. The Albany Spindle cup is a cast brass, highly finished, automatic cup, with soft copper spindle which regulates the flow and causes it to feed only when the machine is in motion. This cup is lasting and economical and is

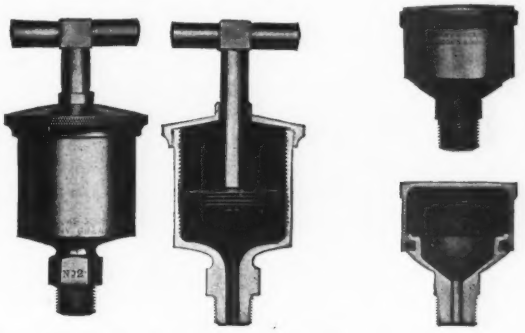


FIG. 3. ALBANY SCREW-FEED CUP

FIG. 6. THE ALBANY PERFECT CUP

adapted for use on crank pins, journals, and shafting.

The Albany Spring Compression cup is of cast brass and provided with a leather packed plunger, which is easily raised by a thumb lock nut. It is excellent on journals. The Albany Screw-feed cup is designed to withstand rough usage, and is for use on marine engines, mining machinery, etc., and of particular value wherever it is necessary to force the grease some distance. The Albany Locomotive cup is a spindle cup designed especially for use on locomotive journals. The Albany Loose Pulley cup has a spring which maintains good contact between the spindle and shafting irrespective of position and yields constant lubrication.

The Albany Pressed and Albany Perfect cups meet the demand for low priced cups and yield good results on shaft bearings, jarring machinery, etc.

DIXON'S FLAKE GRAPHITE

Joseph Dixon Crucible Co., Jersey City, N. J.

WHEN USED AS A LUBRICANT, Dixon's flake graphite is added to either oil or grease to increase its lubricating value and reduce friction, graphite being unaffected by heat, and its endurance much greater than oil or grease, adds materially to the qualities of these lubricants for machinery and bearings which require constant or flooded lubrication. Thus flake graphite is able to provide its lubricating services regardless of the conditions or surroundings that would render an oil or grease alone inefficient, since it is affected by neither heat nor cold. Graphite alone is difficult to distribute, therefore the combination of oil or grease and graphite provides a service which neither alone could give.

Graphite attaches itself firmly to the metal surface by becoming pinned to the minute projections and provides a polish over the bearing surface. This glaze is really a thin veneer of graphite that is smooth and durable, thus in a microscopically rough metal bearing, a bearing of graphite is substituted which requires less lubricant than would otherwise be needed.

Dixon's graphite cup greases are made in 6 degrees of hardness, their consistency varying slightly through a large range of temperatures. They are used where any cup grease is desirable and made for light as well as heavy machinery services.

For air-pump lubrication Dixon's Powdered Flake Graphite, which is derived by a selective process of refining and milling to a minute degree of fineness, is successfully used. The most satisfactory method of feeding this to the air pump or compressor is to mix a teaspoon full of graphite with a pint of regular oil and introduce it from time to time through the regular oil pump or cup. This mixture should, of course, be shaken or stirred before use. Where high temperatures are encountered in the cylinder it is found that graphite sticks to the surface where oil will burn and pass into the air system. Thereby the surfaces of the cylinder and piston are polished with graphite improving the feed, reducing the friction and preventing binding and cutting.

ACHESON GRAPHITE LUBRICANTS

International Acheson Graphite Co., Niagara Falls, N. Y.

FOR LUBRICATION OF PULLEYS and shafting, as well as other parts requiring a lubricant, valuable features are possessed by the new lubricants which contain Acheson-Graphite. Many engineers have long recognized the fact that unctuous graphite possesses unusual merit as a lubricant, because it affords a veneer or film that renders the surfaces highly polished and which will not break down. Naturally, the main purpose in the use of lubricants of any kind is to overcome friction, and where a veneer or polish has been given to revolving or rubbing parts through the use of graphite, the friction is greatly lessened. When applied to metal surfaces, in powder form if possible, or with grease, oil or water, where a carrier is necessary, graphite fills in the irregularities, building up the hollows and burying the minute metal points, thus affording perfect lubrication and preventing the parts wearing away.

During recent years great advances have been made in graphite lubricants as the result of the discoveries and inventions following extended years of scientific research on the part of Dr. Edward G. Acheson of Niagara Falls, who, through the operation of his electric furnace process, has given the world graphite made artificially, which rates very high in purity and is therefore desirable for the purposes of lubrication. Not only is this graphite available in powder form, but the same scientific research has resulted in a process whereby it is successfully suspended in oil or water at will, placing at man's disposal new and extremely valuable lubricants. It is also blended or mixed with grease, this combination lubricant being recognized as of unusual value.

Oildag, one of these lubricants, is Deflocculated Acheson-Graphite suspended in oil. This graphite is reduced to the smallest particles possible of attainment without loosing identity; it is in the colloidal state. It is not intended to improve the quality of the oil, but tests show that the graphite in the oil will accomplish 3 times the work of oil alone.

Another new Acheson lubricant is Aquadag, which is the name given to a mixture of Deflocculated Acheson-Graphite and water. Graphite used in making Aquadag is identical with that used in Oildag. While Aquadag suggests a radical change from present methods it undoubtedly has a great future before it as a lubricant. Inasmuch as it is composed of water and graphite it is apparent that it will not emulsify, oxidize or burn up as will oil. The graphite is a perfect lubricant, the water a decided cooler, and in the use of Aquadag the viscosity of heavy oils is wholly eliminated.

Gredag is another new lubricant made by blending practically chemically pure Acheson-Graphite and a high grade grease, the grease serving as a carrier for the graphite and giving both graphite and grease as lubricants. Acheson-Graphite has a guaranteed purity of at least 99 per cent.

No refining is necessary when it comes from the furnace, as the graphite is made in a temperature over 7,500 deg., and this temperature drives off all impurities in the form of vapor, leaving the graphite of wonderful purity, softness and unctuousness, wholly free from grit.

KEYSTONE GREASE

Keystone Lubricating Co., Philadelphia, Pa.

IN THE MANUFACTURE of Keystone grease, pure natural products composed of refined petroleum, which are not subject to decomposition, rancidity or deteriorization under any working conditions regardless of the speed or pressure, are employed, maintaining within the bearing a noncorrosive film, having a low coefficient of friction. This grease is made in densities to suit different classes of machinery and can be furnished in a light body suitable for use upon bearings of the ring or chain lubricated type, or in a body sufficiently heavy to withstand the pressure that a crushing machine will place upon it.

NON-FLUID OIL

New York & New Jersey Lubricant Co., New York

IN MANY RESPECTS line shafting is the object of much neglect and as a result is accountable for considerable loss and expense. Between the main drive pulley and the remote points to which line shafting may extend there is usually developed an amount of friction in shafting bearings which is out of all reason. A great share of this is due to faulty lubrication.

The use of Non-Fluid oil for shafting lubrication in any type of bearing brings relief from spattering and waste of oil. Different densities are recommended according to the type of bearing, and Non-Fluid oil is especially satisfactory wherever ordinary shafting cups are in use or where special funnel shafting cups may be applied. According to the manufacturer the cost of lubricating a single shaft bearing by means of Non-Fluid oil in tin or steel shafting cups averages less than 3 cents a year. There is no loss through oil escaping and no damage done to goods, belting and floors.

Whether bearings are of ring-oiling, chain-oiling, or other automatic type, or whether caps are fitted with open slots or with tin cups, Non-Fluid oil can be used advantageously. Owing to the tension of belting, the pressure of the line shafting is, in most cases, uniformly directed to a small arc of the bearing and limpid oil is forced to the ends and expelled or is squeezed above the shaft where there is less pressure to displace it.

Non-Fluid oil, aided by its strong adhesive quality, resists shearing and constantly separates bearing and shaft with a thick lubricating film.

Though every lubricant has a definite viscosity, and strength of surface tension, these properties do not determine the permanency of the lubricating film which an oil will present in service. The viscosity of fluid oil begins to dwindle rapidly when heat accumulates in the bearing. Heat also reduces the strength of

its surface tension and the thickness of the film it forms upon the bearing.

Non-Fluid oil will not creep along a shaft from the ends of the bearing. It will go only so far as there is pressure to spread it, so it must stop at the end of the bearing. It never accumulates there in sufficient quantity to drip.

RANDALL GRAPHITE LUBRICATOR

The Strong, Carlisle & Hammond Co., Cleveland, Ohio

THIS IS A MECHANICAL device put up in practical form for reducing friction in Babbitted boxes. It is composed of pure graphite held by a bond in the form of tapered cones which are attached to a fine copper wire screen. To apply these to a boxing, a piece of the sheet is cut off the full length of the box to be Babbitted and wide enough to reach not quite half around the journal so that it will not reach to the top of the half box. This piece is shaped to a half circle a little smaller than the journal to be Babbitted. This is now placed upon the journal or mandrel so that the straight rows run lengthwise of the box. It is then tied with fine copper wire wound spirally.

The box is then Babbitted in the usual manner the metal surrounding the graphite cores; the small ends of the tablets should always be placed in contact with

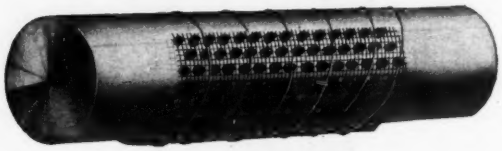


FIG. 1. METHOD OF BINDING SHEET GRAPHITE TO SHAFT FOR BABBITTING

the journal so that the wire cloth will be imbedded near the bottom of the box.

It is claimed that the life of the bearings Babbitted in this way is increased several times and that the saving

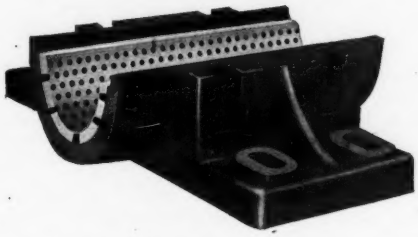


FIG. 2. HALF BOX MADE WITH RANDALL GRAPHITE SHEET LUBRICANT

of oils and greases is at the same time reduced to a minimum.

MICA FLAKE LUBRICANT

United States Mica Co., Chicago, Ill.

PURE WHITE MICA ground and refined by a special process to varying degrees of fineness, according to the manufacturing needs is used in the manufacture of Mica Flake Lubricant. This product is used in connection with lubricating oils which aid in distributing the flakes to the uneven places in the bearing. The flake formation of mica is the quality which characterizes the lubricant. No matter how finely the flake is ground, it is still a flake and its peculiar formation is unchanged. When ground to a fine powder, each individual particle is a flake, a thin, flat piece of mica, presenting 2 smooth parallel surfaces, with feathery edges.

The flakes enter the cracks and pits which appear in rubbing surfaces and fill them. If the surfaces of any bearing have become irregularly worn, due to the heavy loads put upon them, or from other causes, the mica flake fills in and overlays until a new surface of symmetrical outline results. Thus by presenting a uniformly true and smooth bearing surface mica gives the lubricating oil full play and effectively keeps the bearing surfaces apart. The flakes, with their feathery edges, slip readily into the film of oil and rotate with it between the bearings.

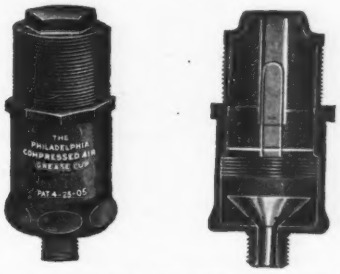
Mica flake is used in the same manner as graphite. It does not cake or harden and will not crush out of service under heavy loads. Being pure white mica, the flake itself will not damage or soil fabric or material, and even mixed with oil it will not blacken or discolor.

THE PHILADELPHIA COMPRESSED AIR GREASE CUP.

Universal Lubricator Co., Philadelphia, Pa.

THE PRINCIPLE OF THE Philadelphia Cup may be described as automatic. The cup consists of 2 sections, the lower half threaded all the way down on the inside, and the upper half threaded its full length on the outside and made to fit into the lower half. The upper half contains a flat metal disk which swings loosely from the center and acts simply as a means for keeping the grease level in the cup while feeding.

The lower half of the cup is filled level full with grease, the metal disk being laid gently on the surface, the upper half is screwed in about quarter of its length. By doing so it will be seen that the air entrapped in the upper half of the cup has been compressed into a space 25 per cent less than what it originally occupied. Under this condition the air is bound to expand, thus forcing the grease into the bearing.



EXTERIOR AND INTERIOR OF THE PHILADELPHIA COMPRESSED AIR LUBRICATOR

The Philadelphia cup exerts only enough pressure to keep the grease feeding, gives the bearing all the lubricant that is necessary, and always of the same consistency as when originally started. Another feature of the Philadelphia cup is that when the machinery stops the cup stops feeding. The pressure back of the grease is so light that the journal has to be turning to permit it to feed. Under such conditions there is no waste.

Having atmospheric pressure on everything within the cup to start with, we can increase that pressure without in any way affecting or changing the grease. On the other hand, if pressure were applied to the disk above by a spring or other mechanical arrangement thus converting it into a piston, we should encounter the difficulties now avoided.

ROPE TRANSMISSION

TWO KINDS OF ROPE transmission are used, one the wire rope for long distances, and the other cotton or manila rope for distribution about a plant. The fibre rope transmission is again divided into the English or multiple wrap and the American or continuous wrap. Each has, of course, its advocates, but the American system seems to be more commonly used in this country. The English system was a development of transmission by belts, a single rope being used to replace a small belt and more ropes added in order to get greater power.

Rope drives are of advantage where large amounts of power are to be transmitted over considerable distances; where future growth is to be provided for; where centers of driving, and driven shafts are closer together than can conveniently be taken care of by belts; where driven and driving shafts are not parallel.

WIRE ROPE

WIRE rope is usually used in single wraps for the transmission of power. and more commonly for considerable distances out of doors. The sheaves are usually of large diameter to give high speed of the rope, thus permitting the use of a small rope and keeping down the stress in the wire. Much of the data in regard to the use of wire rope for transmission is taken from a volume on the transmission of power by wire rope, published by John A.

WIRE ROPE DRIVE AT GREAT FALLS, MONT.

Roeblings Sons Co. and from the Blue Book of the Trenton Iron Co.

Span and Strain

WHERE the distance is not greater than 400 ft. a single loop system will do, using, if necessary, idler pulleys to carry the slack. When greater distances are to be traversed, usually successive loops are employed, the driving sheave of the second loop being keyed fast to the shaft which carries the driven sheave of the first loop, or the 2 loops may be run on 2 grooves of the same sheave wheel.

In his book on Power Transmission, Bell gives as the efficiency for wire rope span, for a single span, 96 per cent; 2 spans, 94 per cent; 3 spans, 93 per cent; 4 spans, 91 per cent; 5 spans, 89 per cent; 6 spans, 87 per cent, each span being from 300 to 400 ft. in length.

Spans shorter than 70 ft. require very heavy rope or tightening sheaves to give sufficient pull, or more than one wrap around the sheaves, and frequently short transmissions with wire rope are not satisfactory. For any span the Roebling Co. considers that a deflection when at rest of 1/36 of the span gives tension enough to develop the power that the loop will safely transmit, while the Trenton Co.'s rule is the deflection for steel rope should be 0.0004 times the length of the span squared; for iron rope twice that amount. Too great a strain on the rope not only causes rapid wear of the rope but makes trouble with the filling which is used to increase the friction between the rope and the sheaves.

Ropes

ROPE used is generally made of 6 strands having 7 wires in each strand, and a hemp center, although some prefer, particularly for small powers where it is desirable to use as small wheels as possible, a rope with 19 wires to the strand. Advantage, other things being equal, is with the 6 by 7-wire rope because the wear on the outside wires reduces the section of metal less. They require, however, larger sheaves. For ordinary usage the ratio of diameter of wire to diameter of rope is for 7 wires to the strand, 1 to 9, and for 19 wires to the strand, 1 to 15.

SECTION OF SHEAVE FOR WIRE ROPE

As between iron and steel rope, the Roebling Co. considers that usually steel is not necessary for spans shorter than 200 ft., as a heavy rope is needed in order to give the necessary tension to produce the required friction between rope and wheel. Using a smaller steel rope will make it necessary to stretch it tighter, thus increasing the friction on the bearings and causing a greater strain on the filling of the grooves in the wheel. The Trenton Co. advocates steel rope for all transmissions.

In deciding the size of rope to use, attention should be paid to the wear, because after the crown of the wire is worn by rubbing on the sheaves, the bending of the strands as the rope passes around the sheaves is concentrated on the crown, and the strain is considerably increased. In general it is well to use as large a sheave as possible in order to cut down this bending, the diameter for iron rope for best results being not less than 100 times the diameter of the rope for a 7-wire strand, and 60 times the diameter of the rope for a 19-wire strand. For steel rope the least sheave diameters are about half of those for iron rope. Grooves in the wheel are made somewhat V shaped, as indicated in the cross section of the rim, and at the bottom is a chamber into which filling is introduced, this filling consisting usually of alternate blocks of rubber and leather. The rope runs on these blocks and does not touch the metal of the rim. In some cases blocks of hard wood are used, but their transmitting power is 28.5 per cent less than for leather and rubber.

Whatever form is used, it should have a depression at the center so as to throw the rope away from the metal.

Sheaves

IN order to run smoothly, sheaves must be accurately balanced and in perfect alinement, with the shafts exactly parallel. If this is not carefully attended to the rope is likely to jerk and destroy itself as well as the filling to the wheels. It is of advantage to make the sheaves quite heavy as a flywheel effect will thus be secured which will help towards steady running, and tend to prevent flapping of the rope.

When it is necessary to have 2 loops at an angle with each other, bevel gearing is usually introduced for the purpose. Sheaves up to and including 12 ft.

RUBBER AND LEATHER LINING FOR SHEAVES

in diameter are made of cast iron and when they are larger than 12 ft. they are usually built up with wrought-iron arms and cast-iron rims.

As in the case of any band connection, it is better to have the driving side at the bottom of the pulleys as the sag produced by the driving tends to wrap the rope more closely around the sheaves. The horsepower which a rope can transmit is equal to the difference in tension between the tight and the slack sides, times the speed of the rope in feet per minute, divided by 33,000, and Roebling states the difference in tension between the 2 sides of the rope, if the deflection is 1/36 the span, is equal to the weight of the single run of rope suspended between the sheaves, multiplied by 3. The velocity is usually given, or is assumed at some value not over 5000 ft. a minute.

Large sheaves are necessary for 2 reasons, first to get a high rim speed at a comparatively low number of revolutions per minute, and second, in order to keep the 2 parts of the rope at considerable distance apart, so that there will be no danger of swaying together.

Up to and including 12 ft. in diameter the sheaves are usually made of cast iron, those up to 10 feet being in a single casting and from 10 to 12 ft. cast in halves and bolted together. For sheaves more than 12 ft. in diameter a built-up construction is ordinarily used, having cast-iron rims and wrought-iron arms. These are bolted together and the grooves are turned after assembling. If more than 250 hp. is to be transmitted, except for very long spans it is better to use 2 or more wraps around each pulley, as this permits the use of a lower tension in the rope without slipping, and avoids rapid cutting out of the filling in the groove.

For spans of over 200 ft., it is better to use steel rope, as the weight will then be sufficient to give all the tension desired even with the lighter weight of rope.

In ordering endless wire rope, the exact length of the rope or exact dimensions of the system should be given, these dimensions including the diameter or circumference of the pulleys, and the distance of the pulley shafts from center to center. If it is necessary to splice the rope in place, an allowance of 20 ft. should be made for the splice. In general, the sag of the rope should be not much over 1 foot per hundred on the tight side, and 2 ft. per hundred on the slack side.

Power Transmitted

FOR wire rope transmission the power can be found as follows, as given by William Hewitt: Multiply the entire weight of all the moving parts, including the rope, the terminal sheaves and shafts and the intermediate sheaves and shafts, by 0.000006. Subtract this product from the diameter squared times a constant given in the table herewith, and multiply the remainder by the speed of the rope in feet per second. The result will be the horsepower capacity of the transmission.

The quantity to be subtracted is, for ordinary conditions, so small as to be negligible, hence the rule becomes: constant $\times$ diameter squared $\times$ velocity in feet per second $=$ horsepower.

In the case of extra long transmissions of several hundred feet, the method recommended by the Trenton Iron Co. is to use a rope larger than would ordinarily be employed and run it at a moderate speed, supporting it at intervals of about 100 ft. on sheaves of comparatively small diameter. If it is necessary to

WIRES FROM INTERIOR OF NON-LUBRICATED ROPE

turn angles, however, the sheaves used at the angles must be of a size corresponding to the safe limit of bending, the same as for the driving and driven sheaves. The rope may be run under a high working tension much greater than that which in the ordinary system would cause the rope to slip on the sheaves.

In the lubrication of wire rope it is necessary that the interior of the rope be lubricated as well as the exterior, otherwise the strands will wear upon each

CONSTANT FOR POWER OF LONG WIRE ROPE SPANS

C FOR STEEL ROPE	NO. HALF LAPS		
	1	3	5
ON IRON	5.61	10.62	12.16
" WOOD	6.70	11.51	12.66
" RUBBER & LEATHER	9.29	12.70	12.97

FOR IRON ROPE C IS HALF THESE VALUES

other badly and also corrosion and pitting are likely to be set up. The lubricant for wire rope should, therefore, be waterproof so that it will not wash off and should also be heavy enough in consistency so that it will penetrate to the interior between the strands and will stay there for some time without being squeezed out. Special lubricants are always necessary. It is not good policy to use any greases having acid in them, as they will rot the hemp core which is commonly employed in transmission rope.

AMERICAN WIRE ROPE

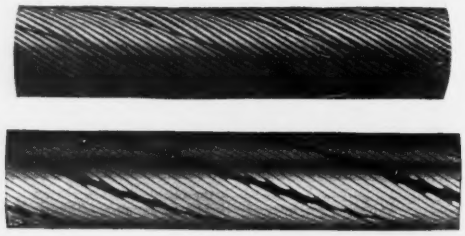
American Steel & Wire Co., Chicago, Ill.

WIRE ROPE FOR transmission purposes is made by the American Steel & Wire Co., both steel and iron, and of all standard sizes. In the regular lay of rope the wires in the strand are laid to the left and the strands are laid to the left, while in the Lang lay, which is specially fitted for hoisting and haulage, the strands and wires are both laid the same way, either right or left. The company recommends that the load on the rope should not exceed 1/5 the ultimate or breaking stress, and the stresses given in the Practical table for wire transmission rope are the latest scheduled by this company.

FLATTENED STRAND ROPE

A. Leschen & Sons Rope Co., St. Louis, Mo.

This rope takes its name from the shape of the strand, which is constructed with an oval core so that the outside surfaces of the strands have a flattened elliptical shape, giving a greater contact surface with the sheaves,



LESCHEN FLATTENED STRAND ROPE, NEW AND AFTER USE

thus increasing the grip of the sheaves on the rope and also distributing wear more evenly over the strands. The illustrations show the flattened strand rope both as new and after continued use. The wearing surface in the type shown is approximately 150 per cent greater than that of round strand rope. This company also makes round rope in the ordinary and in the Lang lay of iron or of various grades of steel, its special brand being the Hercules rope, which is made in both round and flattened strand for especially heavy loads and is distinguished by having one colored strand.

FIBROUS ROPE DRIVES

By William B. Hosford*

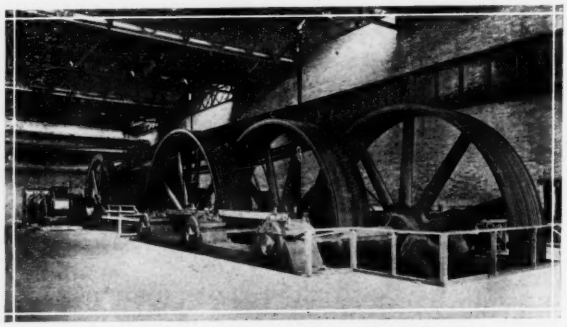
THE USE of manila rope is growing in favor all along the line. There are 2 distinct plans or systems of manila rope drives in use at the present time for the transmission of power, viz., the so-called English or German system, and the American system.

Systems of Rope Driving

THE English system consists of a number of separate and independent loops of rope running side by side in separate parallel grooves with no other tension than that caused by their own weight in suspension between the wheels upon which they run. This system we learn was introduced in England about 1865 by James Combe, who commenced at that time his experiments with hemp and manila rope. And from then on to the present, the use of manila rope for transmission of power, especially in large units, has gradually increased.

In 1883 the Dodge Manufacturing Co. introduced the so-called Dodge American System.

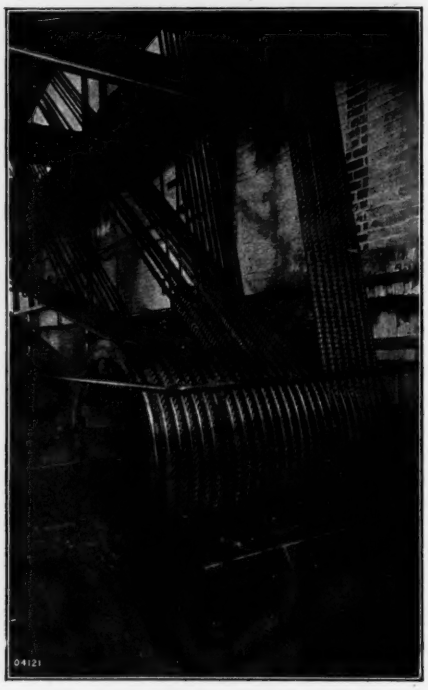
This system uses but one continuous rope, wound over the driving and driven wheels as many times as required to transmit the power, the return rope on the



ROPE DRIVE FURNISHED BY MESTA MACHINE CO. TO JONES & LAUGHLIN STEEL CO.

slack side forming a loop over a winder and traveling or flexible tightener. This tightener is controlled by a weight so that it may automatically regulate the tension in all the wraps of rope.

The American system has been improved greatly since its introduction, as experience and study have



EXAMPLE OF ENGLISH DRIVE FROM THE C. W. HUNT CO.

developed it. The English system requires a splice in every wrap of rope. In the American system, the rope is one continuous piece, requiring but one splice.

Tension for Driving

THE English system depends upon gravity for tension; hence, to increase the tension larger diameter ropes must be used to augment its weight. The

*Vice-president the Dodge Mfg. Co., Michawaka, Ind.

slack side of these ropes being loose, they vibrate and have a tendency to jump out of the grooves. To overcome this, deep grooves with high partitions are made in the wheels. These conditions increase the cost of the wheels, as heavier rims to accommodate the deep grooves are required. The expense of added number of splices, handling larger and more combersome rope all combine to discourage the use of the English system.

To splice a multiplicity of ropes and secure uniformity of driving effect, is difficult, because the shortest loops will carry the burden of the load and are subject to rapid wear and liability to breakage. Again, the ropes carrying the heaviest strain would not travel evenly with the looser ones, causing a differential in case of a difference in diameters of driver and driven, which would produce undue wear on the ropes.

The automatic adjustable tension carriage of the American system gives better results, by reason of the assured uniformity of tension on all of the ropes, relieving the splice of any special strain, such as is thrown onto those of the overloaded ropes in the English system.

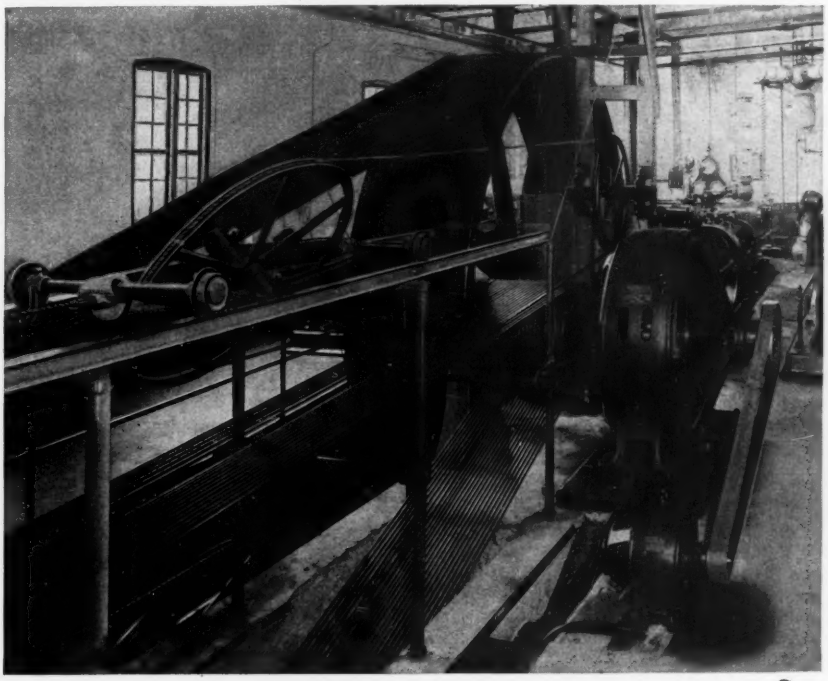
In the American system, the tension being regulated automatically, the ropes run without vibration, thus permitting the use of shallower grooves, lighter wheels and lighter rope, and producting a saving in the power required to revolve the heavier (English groove) wheels, and a saving in friction.

Rope Drive Design

THE American system, under the direction of an experienced engineer, can be designed to drive in any direction or at any angle. A building may be isolated at any convenient distance from the power, the machinery set up as desired and the drive designed to connect the power, leading the ropes in the most convenient line.

It has been said that "a little knowledge is a dangerous thing." This is quite true in designing rope transmissions. The engineer designing a drive may understand the theory, but fail in practice and experience. Experience is absolutely indispensable in this line, as there are no 2 installations just alike.

Each drive requires individual treatment, from the fact that the speed of shafts, amount of power required, distance between centers, and other varying conditions, differ in every case. In one installation the load and power will be steady, in another fluctuating; each case requiring the utmost skill and recourse to long experience by the most skilled engineer.



ENGINE AND GENERATOR DRIVE AT THE CENTRAL PAPER CO., MUSKEGON, MICH.

Knowledge can be imparted to others, but it is impossible to transfer the experience of one to another—to confer the ability to anticipate unknown conditions before they come up—to impart the experience of the past as guides for judgment in laying out new work where conditions differ from those already covered in practice.

When an engineer has tried a thing and found it impracticable, he can, if consulted, save the next man no little expense and trouble by warning him against making the same experiment.

We are not like the patent medicine people, advising the rope drive as a panacea for all mechanical ills. There are innumerable cases where a rope drive would not be suitable or appropriate, and to know where to draw the line, so to speak, to know when a rope drive would not be the best or most successful means to employ, and to suggest the best substitute, is worth something. If a rope is best for the case, then to know how to plan it to work successfully, having in mind the difficulties to be overcome, the troubles to be avoided, and how to adapt it to the conditions existing is the important thing.

Care of Rope Drives

TREATMENT or management of rope drives that are running is a matter of no small moment, and perhaps a few words on this point may not be uninteresting.

Running rope should never be allowed to touch anything but the wheels upon which it works, and it should not chafe against the sides of the grooves of the wheels.

In the American system the tension weight should have careful attention. Theoretically the tension weight should be about 4 per cent of the breaking strength of new rope of the size used, plus the friction of weight rope sheaves and resistance of the traveling carriage on the track.

These resistances are an unknown quantity. The answer is, use weight enough to make the rope run without vibration and to prevent slipping in grooves. This will permit an easy,graceful sag in the slack side of the drive, indicating that it is running easily and not under undue strain. This condition relieves journal friction and heating and increases the life of the rope.

Cases have been known where too much weight was used, causing the ropes to assume almost straight lines. This produces a condition similar to a tight belt, causing undue journal friction, if not heating. Too much weight causes internal wear in the rope, cutting the fiber where the strands rub together, rapidly deteriorating the rope.

Rope Dressing

ROPES should not become dry or fuzzy on the outside. There are several dressings on the market, many of them causing a rope to be more or less greasy and non-adhesive.

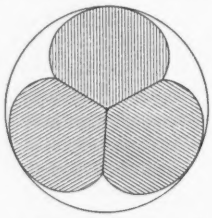
Ropes running out-of-doors need dressing more carefully than those in buildings. Dressing should never be applied when rope is damp, as it will cause mildew and rot. For outdoor drives, a very dry spell is the best time to treat with dressing, which, when properly put on, will prepare the rope for a long, hard winter.

The tension carriage should be prevented from reaching the end of the track, or weight from resting on anything. This condition would cause the rope to become slack and run off the carriage wheel, and might do some damage.

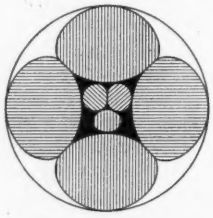
During a dry time ropes will stretch and be longer, but the carriage will take up this increased length; if near the end of the track at the beginning of the dry time, it will go to the end in a short time if not looked after. In taking up or shortening the rope during a dry spell, the splice should be made so as to let the carriage away from the inner end of the track and so allow room to travel forward as the rope shrinks in humid atmosphere. Weight rope sheaves need lubricating to reduce friction and wear, and make the carriage more flexible.

Uncoiling Without Kinking

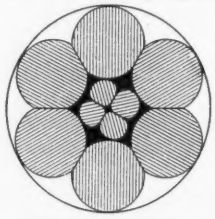
THOSE who are using ropes may have experienced some little trouble and annoyance in taking a new rope out of the coil. There is one way the rope can be taken out without twisting and kinking, yet without putting the coil on a reel and revolving it, which is no small job with a large coil. It is done thus: Find the side of the coil where the end of the rope is in the center hole; turn the coil over, bringing that side down on the floor; reach down through the center and pull that end out through the top, and the rope will come out smooth and without kink.



Three Strand Rope



Four Strand Rope



Six Strand Rope

SECTIONS OF AMERICAN MFG. CO.'S ROPE

FIBROUS ROPE

FOR power transmission, manila or cotton rope may be used, but cotton has usually been found better for small and moderate sized powers, as rather smalier sheaves can be used than would be best for manila, and the fibre grasps the grooves in the rim of the wheel more firmly.

There is difference of opinion between English and American designers, however, as to the relative value of cotton and manila rope. The English engineers claim that the cotton rope is stronger and more durable, while American engineers are as strongly in favor of manila rope rather than cotton. In either case a rope with a long lay to the twist is stronger than one with a short lay, because less strain is put on the fibers in the twisting.

For mill transmission purposes, however, where large sheaves may be used, manila rope seems more durable, has less stretch, and can be spliced with less difficulty. As it has greater tensile strength, a smaller rope can be used than would be possible with cotton and the first cost is less. The 4-strand rope is usually the favorite as it is more nearly round, more flexible and somewhat stronger than the 3-strand, and is not as difficult to splice as the 6-strand.

English and American Systems

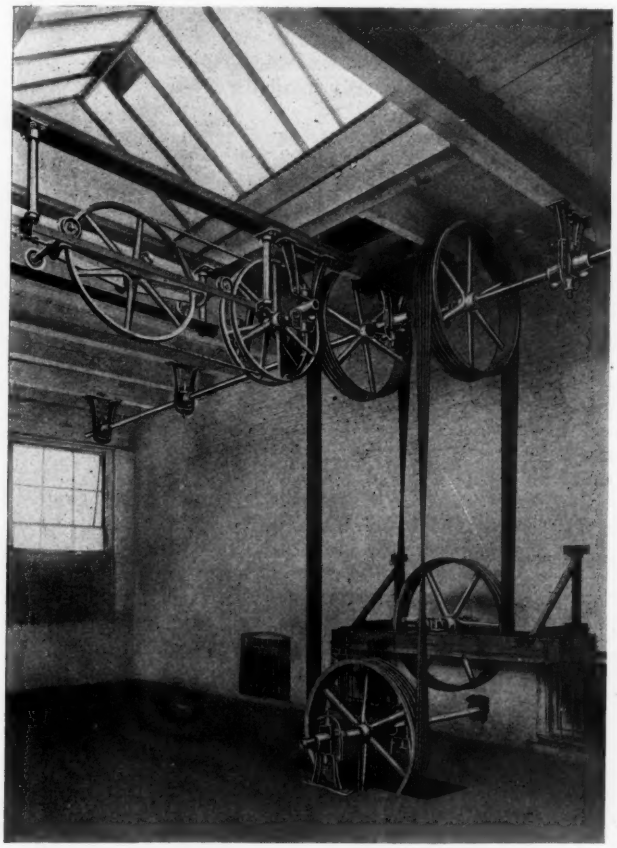
IN deciding as between the English and American systems, the English system is suitable where there is a long distance between centers, from 30 to 125 ft., a fairly uniform load, the driving and driven sheaves of about equal diameters, and shafts nearly enough horizontal so that the ropes will hang into the grooves rather than out of them.

The speed should be kept below 4500 ft. per minute, and the best results are obtained between 3000 and 4500. The sheave is usually made 40 times the diameter of the rope, and rope used is generally from ⅞ to 2 in. in diameter, the multiple system using the larger sizes, and the continuous or American system the smaller.

Sometimes it is necessary to use a sheave whose diameter is less than 40 times that of the rope, but in such a case the amount of power transmitted per rope should be reduced and a larger number of ropes added in order to keep down the wear.

Sizes of Ropes and Sheaves

IN selecting a multiple system, size of rope should be so chosen that the system would carry the required power, if one of the ropes should fail. In determining a rope drive the first thing is to decide on the feet per minute at which the rope is to run, and then from the required speed of the shaft we can

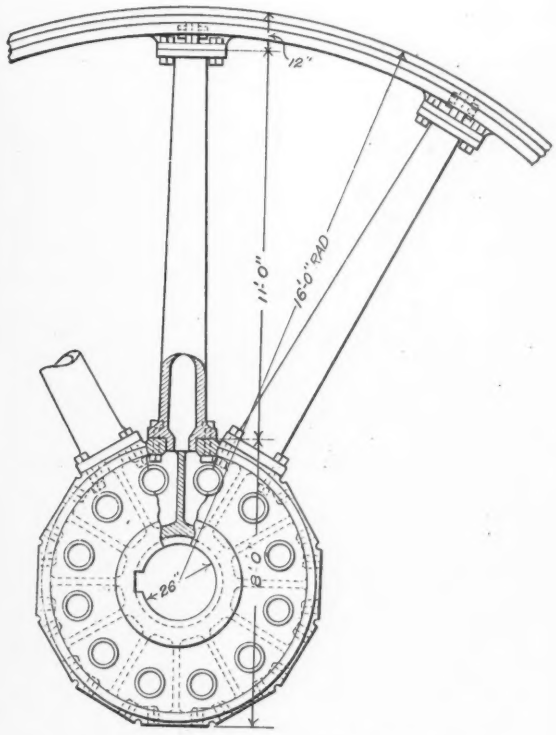


EXAMPLE OF A RIGHT ANGLE ROPE DRIVE, AMERICAN SYSTEM

decide on the size of sheave wheel which should be used. That is, multiply the required turns of the shaft by 22/7 and divide the proposed rope speed by the result. The quotient will be the diameter of the sheave wheel in feet. The amount of force necessary to be transmitted can then be provided for, either by a small number of large ropes or a large number of smaller ropes, but the size of rope which can be used is determined by the size of the sheave wheel. By the rule given above, the rope diameter is 1/40 the sheave wheel diameter.

In laying out a rope drive it is usually best to have a distance between the centers of shafts of at least 3 times the sum of the radii of the driving and driven pulleys in order to get a reasonable number of degrees arc of contact and avoid too quick bending and straining, which is likely to produce whipping of the rope.

In a general way with common practice the tension on the driving side is twice that on the slack side, so that the difference between the 2 which determines the amount of power transmitted is equal to the tension on the slack side. Practice has determined that the maximum tension advisable to put on a rope is 200 times the diameter squared. And knowing the diameter of the rope, from this may be determined the maximum tension, and from the data already given the total tension on all the ropes must be equal to twice that required to transmit the given power. The tension to transmit the given power is



DESIGN OF 32-FT. WHEEL FOR ROPE DRIVE

found by multiplying the horsepower required by 33,000 and dividing by the rope speed in feet per minute.

Allowable Slack

IN general the slack allowed should be as great as possible without having the ropes slip or rub against each other. The amount may be approximated by multiplying the weight of one foot of rope by the square of the distance between centers of sheaves, and dividing by 8 times the tension of the rope. A new rope will stretch considerably for a short time, but after the rope is bedded firmly together the further stretch is slow, and the total should not exceed 5 per cent.

When a rope has stretched so that the sag is 10 per cent of the distance between the 2 shafts, the ropes are running too slack and should be tightened.

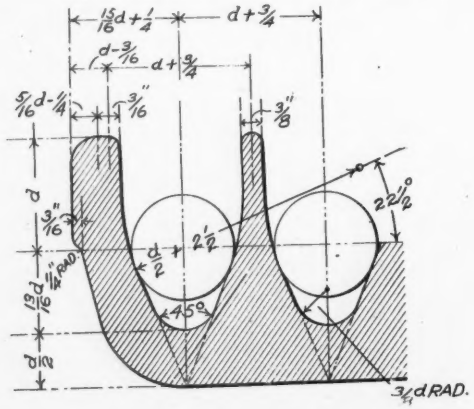
When resplicing rope on a continuous drive, allowance should be made for movement of the tightener in order to take care of shortening of the rope

in damp weather, 2 per cent of the rope length being generally safe. The weight used on the tension carriage in the continuous wrap system should be only enough to prevent slipping and is approximately 160 times the diameter squared of the rope.

In arranging the tension system on a continuous rope drive, a tension carriage should be employed to every 3500 ft. of rope. An allowance should be made in travel of the tension carriage for at least 2 per cent of the total length of the rope, but in many cases more travel than this will be necessary, depending on the conditions of the drive.

Sheaves and Grooves

AS to the grooves in the sheaves, 2 systems are in use, as indicated in the illustrations. Besides giving a narrow rim to the wheel, a sharper angle to the groove will produce a wedging effect, which of course

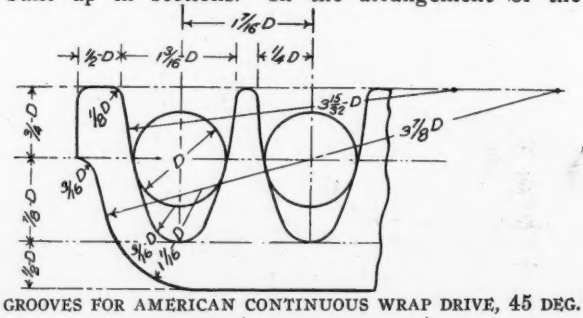


STANDARD GROOVES FOR ENGLISH MULTIPLE SYSTEM

gives somewhat increased power of transmission, but takes up power in pulling the rope out of the groove, and also wears the rope rapidly. For wood pulleys, the semi-circular groove is usually used.

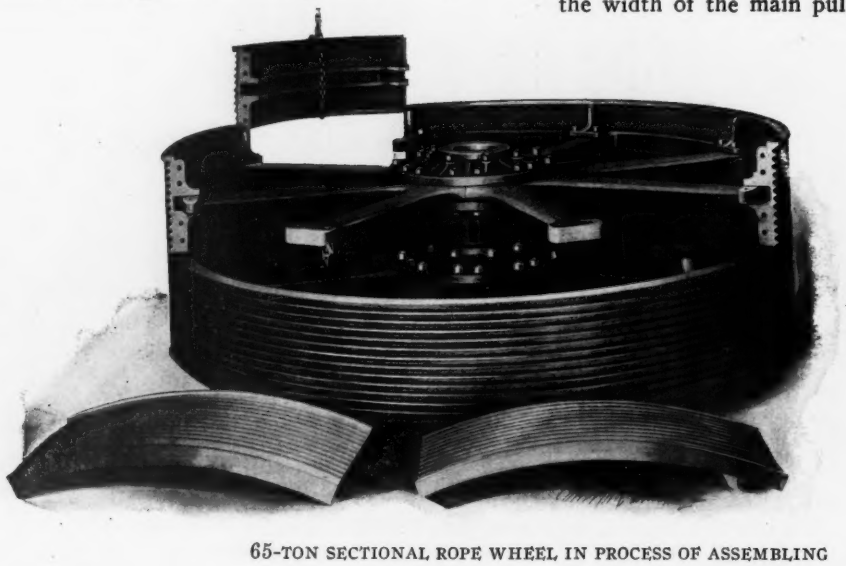
of 3 deg. Above this it is usually necessary to use jockey pulleys or pulleys having a groove inclined to the surface of the sheave to start the rope in the right direction. Crossed drives may be used where positively necessary, but are to be avoided. The best method is to use a multiple rope, 2 ropes being used with an empty groove between them, and the crossing right and left handed so that the 2 center plies are on the driving side. These will then move together without friction and the outer ropes, which are the slack side, are easily kept apart by the inner pair. In the quarter-turn drive the pulleys must be arranged with the slack side on the straight and the tension side on the skew, as otherwise the slack side will not enter the groove.

As for the wire transmission, sheaves up to 8 ft. in diameter are usually made solid and from 8 to 12 ft. are made split; above that they are usually built up in sections. In the arrangement of the

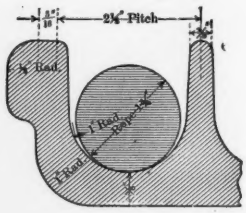


GROOVES FOR AMERICAN CONTINUOUS WRAP DRIVE, 45 DEG. GROOVES (JEFFREY MFG. CO.)

tightener carriage for the continuous rope system, care should be taken that the pulley is so hung as to carry the rope correctly from the leaving side of the main pulley to the on-coming side. This is obtained by the position of the tightener pulley and the angle at which the tightener pulley is set. Also the diameter of the tightener pulley must be in proportion to the width of the main pulley.



65-TON SECTIONAL ROPE WHEEL IN PROCESS OF ASSEMBLING



STANDARD GROOVES FOR ENGLISH MULTIPLE SYSTEM.

Where idlers are used, the bottom of the groove is made U shaped so that the rope simply rides in it and does not wedge.

Where the wheels are slightly out of line the rope may run satisfactorily up to an angle between shafts

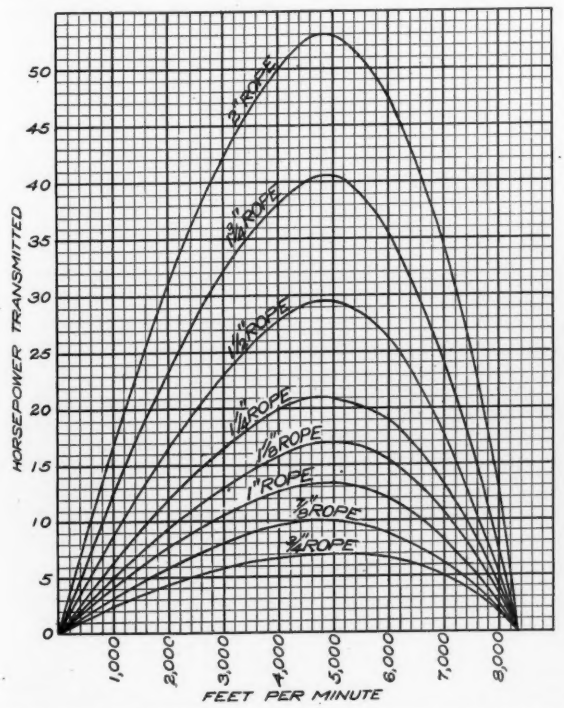
Large and Small Ropes

AS between large and small ropes, although it is true that the life of a rope whether of manila or cotton depends largely upon the work it has to do and the attention it receives, yet other things being equal, the

smaller rope wears out more rapidly than the large one. If the small rope runs over small pulleys the number of flexures is greater, and also the angle of flexure is greater for each time, and both these contribute to rapid wear. It is best if possible to use a rope not less than one inch in diameter, both on account of the wear and because there is less likelihood of breakdown and stoppage with the large rope.

Speed and Horsepower

FOR speeds above 2000 ft. a minute, the effect of centrifugal force increases rapidly, and at a speed of 5400 ft. a minute this force increases faster than the power from the increased velocity of the rope. Flather, in his book on Rope Driving gives as the coefficient of friction for different angles of grooves as follows: For 30 deg., 0.46; for 35 deg., 0.4; for 40



VARIATION OF HORSEPOWER WITH VELOCITY FOR MANILA ROPES

deg., 0.35; for 45 deg., 0.31; for 50 deg., 0.28; for 55 deg., 0.26, and for 60 deg., 0.24. The English accepted angle for the groove is, and this is much used in America also, 45 deg.; it gives a coefficient of friction of 0.31, and it is usually assumed that the rope will cover an arc of 165 deg. on the circumference of the sheave.

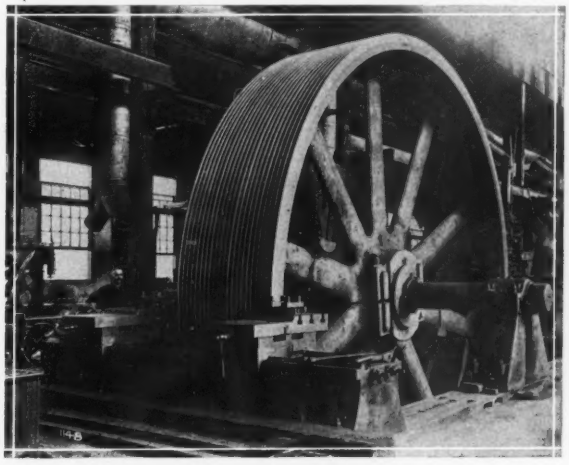
Under these conditions, Geo. V. Cresson Co. finds that the horsepower transmitted by a manila rope will be as indicated in the diagram herewith, the gradual falling away of power with increase above 4000 ft. a minute being due to the effect of centrifugal force already mentioned. The other assumptions upon which this diagram is based are that the rope has a maximum tension in pounds of 200 times the square of the diameter and that its weight is 0.33 times the square of the diameter.

In regard to the diagram for horsepower and velocity, it should be noted that although the maximum power can be transmitted at a speed of 5500 ft. a minute, the wear comes in to modify this result so that the most economical transmission is usually at 4500 ft. a minute. But considering the combined first cost and wear there is little difference from 4000 up to 5500 ft.

Efficiency of Rope Driving

IN general, from 5 to 8 per cent loss may be attributed to the bending, wedging in grooves, differential effect, creep, and all those things which have to do with the rope proper. In addition to this, there is, of course, the loss in the bearings of the sheaves, but this will be less than for a belt drive because a less pull on the rope is required on account of the wedging in the grooves. Flather has calculated that for an ordinary main shaft with the rope making an angle of not over 25 deg. to the horizontal and with rope drive to the jack shaft which is horizontal, the percentage of loss for a 50 ft. shaft will be from 4 to 5.5 per cent with a 2.5-in. shaft; from 4 to 6 per cent with 3-in.; from 4 to 6.25 with 3.5-in., and from 4.5 to 7 with 4-in. For a 100 ft. shaft these values are for 2.5-in., 8 to 9.25 per cent; for 3-in., 8.25 to 9.5 per cent; for 3.5-in., 8.25 to 9.5 per cent, and for 4-in., 8.3 to 10 per cent.

In turning the sheaves, the greatest care should be used to make sure that all grooves are of the same



TURNING GROOVES IN A LARGE ROPE WHEEL AT MESTA MACHINE CO.'S WORKS

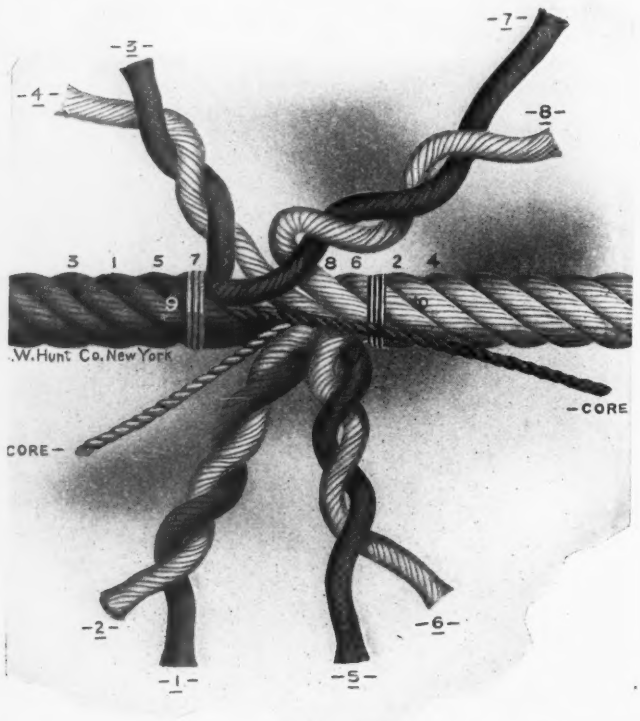
diameter and have the same angle of groove and the same width so that ropes will bed to the same depth. Failure to give this matter attention results in ropes running on different pitch diameters, and therefore at different velocities, producing unequal strain with flopping of the rope and excessive wear. The grooves should be perfectly sound, smooth and well polished, and the wheels should be well alined in order to get the best results. It is important also that the rope should be of uniform diameter, throughout, and particular attention should be paid to the splice to see that the diameter is not increased. The splice is always the weakest point, and any increase in diameter means not only variation in speed, but rapid wear of the splice, which will soon give out.

For light work, grooves are sometimes used with straight sides, but for heavier work the groove with the curved side is preferred, and where the rim with a straight inner face would be heavier than is called for by strength, the inner surface is corrugated to

conform to the bottom of the grooves. If the rims are made especially light, and are very broad it is usual to have a double set of arms in order to carry the strain. Otherwise, the proportions of pulleys are the same as for belting, being as shown in some of the illustrations.

Splicing Ropes

IF a short splice is used, the chances are that there will be an enlargement of diameter. It is therefore considered better practice to use the long or English splice, description of which is given in the book

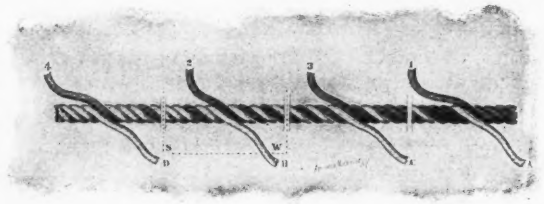


ROPES BUTTED TOGETHER AND STRANDS TWISTED READY TO BEGIN THE SPLICE

on manila rope by C. W. Hunt Co., as follows: The length required for a splice is from 100 diameters, for small sizes, to 80 diameters for large sizes. If the rope is of the continuous wrap type, commencing at one side of the pulleys the rope is passed around from the driver to the driven until the opposite side of the pulleys is reached, thence around the tightener pulley in the tension frame which is hung so that its discharging side is in line with the side of the driver pulley whence the start was made.

After the ends of the rope are brought together, a length equal to half the length of the splice is left beyond the junction point on each end, and a marker is tied so as to divide this space equally between the 2 ends. This marker is a piece of twine tied tightly around the rope, and, in the case of a 1¾-in. rope, for instance, the marker would be tied at 6 ft. from each end, and the strands should then be unlaid from each end back to the twine. The ropes are then butted together and each corresponding pair of strands is loosely twisted to keep them from getting tangled.

The marking twine at 10 is now cut and the strand 8 is unlaid and strand 7 carefully laid in its place for a distance of 4.5 ft. from the junction. It is convenient at this time to tie the ends of strands 7 and 8 against the main part of the rope for convenience in keeping them out of the way. Strand 1 is unlaid for 4.5 ft., strand 2 being laid in its place, and the ends of the cores are then cut off so that they just meet. In like manner strand 3 is unlaid 1.5 ft., and strand 4 is laid in its place. Then strand 6 is unlaid 1.5 ft., and strand 5 laid in its place. All strands are now cut off to a length of about 20 in. for convenience in handling, and the rope has the form shown



STRANDS INLAID AND TRIMMED, READY FOR SPLITTING

in the second illustration, with the meeting points of the strands 3 ft. apart.

Beginning with strands 7 and 8, each is unlaid from the meeting point 3 turns, and the strands are split in halves as far back as they are now unlaid, the end of each half strand is whipped with a small piece of twine for convenience in handling, and half of strand 7 is laid in 3 turns, and half of 8 laid in 3 turns. The half turns where they meet are tied in a

SECURING THE END OF THE HALF STRAND

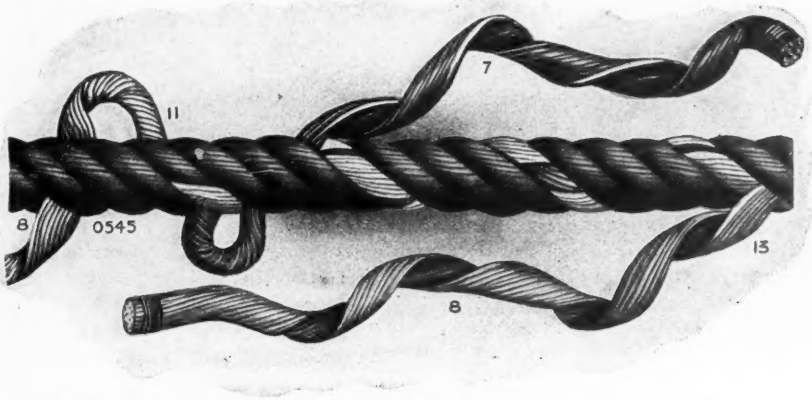
simple knot, making the rope at this point its original size, and the rope is opened with a marlin spike and the half strand of 7 worked around the half strand of 8 by passing the end of the half strand through the rope as illustrated. It is drawn out and again worked around this half strand until it reaches the half strand at 13 in the third figure which has not been laid in.

Half strand 13 is then split and half strand 7 drawn through the opening thus made and tucked under the next 2 strands, as shown in the fourth illustration. Then the remaining half of strand 8 is wound around the other half of strand 7 in like manner, and after each pair of strands has been treated in this manner the ends are cut off at 12, leaving them about 4 in. long. These ends will in a few days draw into the body of the rope or wear off, leaving the entire rope of uniform diameter so that the splice can hardly be detected.

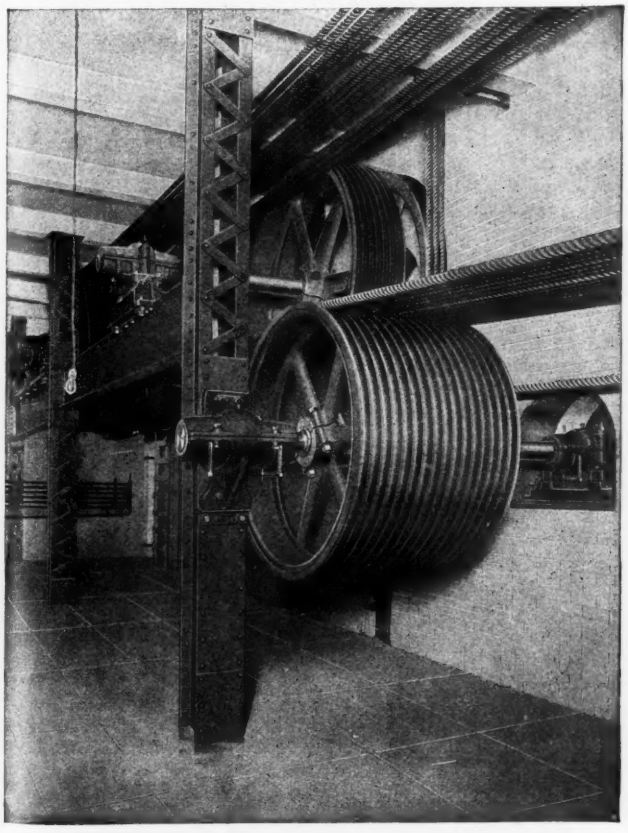
For a 3-strand rope the operation is similar, except that after unlaying the ends and replacing one of the strands by its mate for 4.5 ft. from the joint, the second strand is replaced on the opposite side of the joint, and the 2 remaining strands are split and halves are interwoven as in the case for the 4-strand rope.

Splicing Wire Rope

In making a splice of wire rope the method of procedure is the same as for a transmission splice in 6-strand manila rope up to the point where the strands have been unlaid and replaced by corresponding strands, so that there are 6 points of meeting of the strands equally spaced. The ends are then temporarily secured by wrappings of smaller wire or cord and a rope clamp is fastened to the rope on each side of a meeting point so as to untwist the lay of the rope.

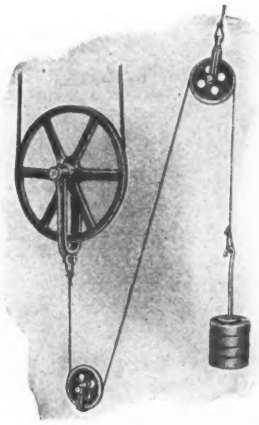


PASSING THE HALF STRANDS THROUGH THE ROPE



EXAMPLE OF HEAVY ALLIS-CHALMERS ROPE DRIVE

The end of each strand is cut off to a length of 12 in. from the meeting point, the lay of the rope opened up and the hemp core cut out for 12 in. each side of the meeting point. The projecting end of the strand is then tucked into the center of the rope in place of this core and the clamps twisted back to close the twist of the rope, any unequalities being taken out with a wooden mallet. This operation is repeated at each meeting joint of the strands.



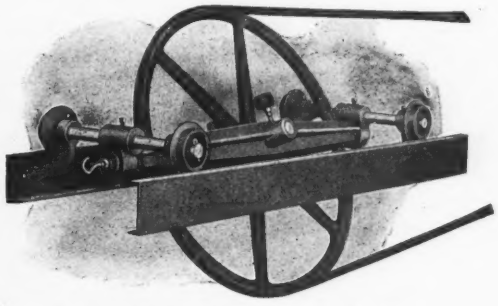
ALLIS-CHALMERS GRAVITY TENSION

It is better to splice the ropes off the sheaves if possible, but where this cannot be done rope must be placed around the sheaves, drawn taut by pulley blocks and clamps, and the splice made in place.

MANILA ROPE DRIVE

Allis-Chalmers Co., Milwaukee, Wis.

THIS COMPANY MAKES a full line of sheaves, shafting carriages and bearings for manila rope driving and installs either the American continuous or the English multiple system, as may be desired. It recommends that the driving sheaves should not be less than 40 rope diameters and driven sheaves not less than 30, that the bend of ropes should be taken always in the same direction where possible. That for short center drives 10 or 12 laps are all that one tension carriage should take care of and that under ordinary conditions there should be a tension carriage for every 3,000 ft. of rope.



GRAVITY INCLINED TENSION WHEEL

A few large ropes are to be preferred rather than a number of small ones. Sheaves are furnished in diameters from 12 to 120 inches and with 1 to 20 grooves. One of its drives as installed in a large flour mill is shown in the larger illustration and 2 methods of installing the tension carriage are illustrated in the smaller figures.

OLD COLONY TRANSMISSION ROPE

Geo. B. Carpenter & Co., Chicago, Ill.

IN THE MANUFACTURE of this rope the entire effort is to make the best rope possible by the use of carefully selected fiber and care in the manufacturing process by workmen who have had 25 years' experience in the business. The thought of the makers is to have a rope which will be as nearly uniform as is humanly possible and on which dependence can be placed for the important work of transmission.

It is made in either 3 strand, 4 strand or 6 strand, and is distinguished by having a single green yarn in each strand. The Geo. B. Carpenter Co. sells this with the distinct understanding that if in any instance the rope does not give reasonable service the company is ready to make good any defects, a policy which shows the earnestness of its endeavor to have the rope of the best possible quality. The company also makes a hoisting rope of the green thread quality.

COLUMBIAN ROPE DRIVE SYSTEM

Columbian Rope Co., Auburn, N. Y.

ROPE DRIVE IS particularly useful and quite indispensable in transmitting power of great magnitude, or under unusual operating conditions, such as out-of-doors, or over and around obstructions. It is used especially in textile mills, as no static electricity is produced by the friction of the manila rope in the grooves of the pulley, an important point for such manufactures, as the quality of the textiles depends to a great extent on the entire elimination of this factor.

In the multiple system, which consists of a series of several independent ropes running side by side in the grooves of the pulley, if 1 or 2 ropes break, the drive is unaffected, as the remaining ropes will carry the load until the broken ropes can be conveniently repaired. This is the great advantage of the English system, and for this reason it is used on the main drive from the main shaft.

The continuous system consists of a single rope wound back and forth between 2 pulleys as many times as may be needed for the amount of power to be transmitted. With this system, it becomes necessary by some device to pass the rope from the outside groove of the driver pulley back to the diagonally opposite outside groove of the driven. This is accomplished by a movable carriage which automatically adjusts the slack, keeping the tension on the rope uniform at all times, by taking the rope at the point where the slack accumulates, and passing it over pulleys mounted in a carriage so weighted that it will move backward or forward, thereby keeping the tension on the rope uniform at all times and under all conditions.

In this system the power is transmitted entirely by one rope, so that there is danger of the rope breaking, allowing the engine to race. If ordinary care is exercised, this danger becomes almost negligible, as manila rope always gives unmistakable signs of wearing out in sufficient time so that a new rope may be substituted.

The continuous system is the more flexible and is used in places where the multiple system cannot be used, but for the drive direct from the engine and the drives from the main shaft the English system is the better, as in these places the item of safety is of utmost importance.

There are many earnest advocates of the continuous system and equally ardent partisans of the multiple; the Columbian practice embraces the use of both systems in the same mill; the multiple system for the drives from the engine and main shaft, with the continuous system for distributing power about the mill, outside or in rather inaccessible places.

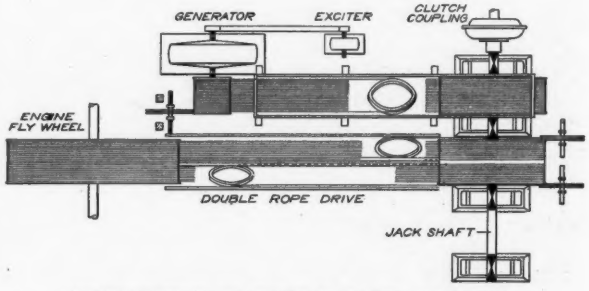
Every form of power transmission has its own peculiar advantages which make it adaptable to certain classes of industries, but where any of the following factors are important the rope drive will be particularly favorable; large amounts of power, 1000 to 2000 hp. being easily handled; long distance transmissions, 175 ft. being easily covered with no idlers and any distance with the use of idlers; where steadiness is demanded as the light weight and elasticity take up variation of the load; where quiet is essential; where future increase of power is to be provided for, as a few extra grooves in the sheaves will take care of the matter, or larger ropes may be substituted for smaller; power transmitted at angles and around corners or obstructions.

DODGE AMERICAN SYSTEM OF ROPE DRIVE

Dodge Manufacturing Co., Mishawaka, Ind.

WHILE THE GENERAL principles of the Dodge System are firmly established as the result of 25 years of experience in this particular line, each problem of rope drive is made a special case of design to suit the conditions. The Dodge American system is, as its name implies, a single rope system with tension carriage, and by the Dodge Mfg. Co. the 60-deg. groove is used as they have found it to hold without slipping as large a load as the rope can economically transmit, and it permits the rope to roll in and out of the groove with small friction and wear.

Life of the rope was one of the important considerations in the adoption of the 60-deg. angle, but there are cases where the Dodge Co. finds it desirable to use 45-



ARRANGEMENT OF CENTRAL PAPER CO. DRIVE

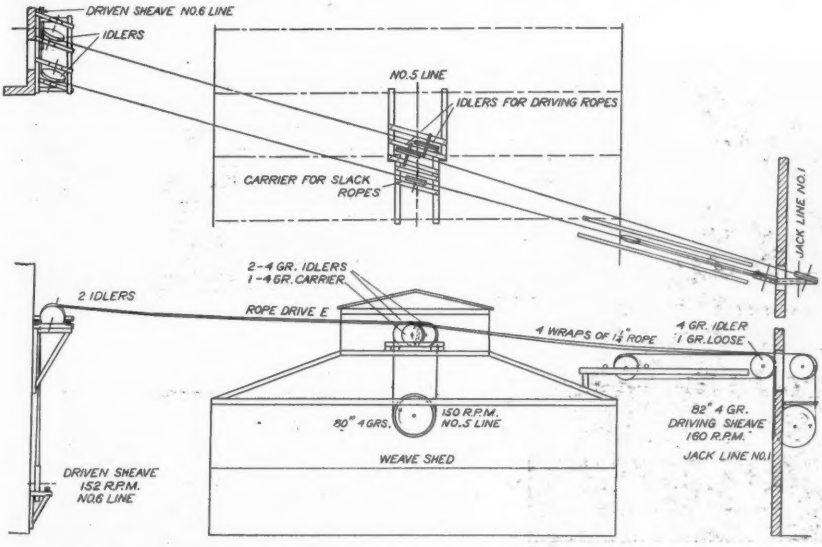
deg. grooves as, for instance, when there is great difference between the diameters of driving and driven sheaves so that the arc of contact on the small sheave is reduced, it is generally necessary to use a 45-deg. groove on the small pulley. Such a condition frequently arises in driving a medium speed dynamo from a Corliss engine. The grooves on the engine wheel will be 60 deg., while those on the dynamo pulley will be 45 degrees. Where difference in diameters of the driving and driven sheaves is not great, the 60-deg. grooves are found entirely satisfactory.

For drives where the distance between centers is very short, such as is frequent to drive the rubber mills in rubber works, it has been found that the rope drive can well replace the heavy gearing formerly used. Such drives have been installed in the works of the Mechani-

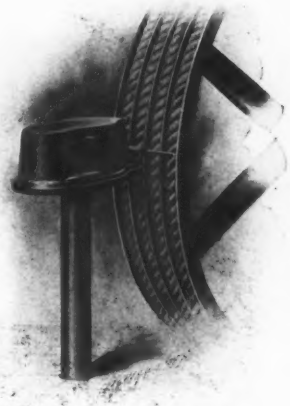
cal Rubber Co., at Cleveland and Chicago, in those of the Morgan & Wright Co., Detroit, and in many rubber mills at Akron, O. The Dodge Co. has installed some 20 drives during the last 6 years, with 60-deg. grooves in every case, and in no case has there been a slippage.

On a test of such mills, feeding the rolls as fast as possible with crude rubber, the ropes did not slip, although in some cases the engine was slowed down. Another instance of short center drives is pulp and paper mills where the load is severe. In one instance, the Dexter Sulphite Pulp & Paper Co., Dexter, N. Y., installed in 1898, with short centers, is still running with the rope originally put on.

An example of indoor driving showing the compactness possible, is that of the Central Paper Co., at Muskegon, Mich., in which there is shown both the photographic view looking from the jack shaft toward the engine and generator, and also the arrangement of the drive in line drawing.



ARRANGEMENT OF COMBINATION DRIVE FROM MAIN MILL TO OTHER BUILDINGS; FIRTH CARPET CO.



TELLTALE APPARATUS ON ROPE DRIVE

With the single rope system it is necessary to use a take-up and in the Dodge system this is arranged for 2 specified purposes, first to take up the slack and control tension in the drive by running the slack loop over a pulley on the tension carriage, second to deliver the rope back to the opposite side of the drive after winding across the faces of the wheels.

This take-up may be placed at any point on the slack side of the drive and several types of tension carriages are in use, the one most commonly installed being the horizontal 4-wheel type. The yoke in which the wheel runs is fastened to the axles by clamp boxes and is, therefore, adjustable horizontally as well as vertically, making it possible to get a fair lead in and out of the grooves, even if the track is not exactly in the position shown in the drawings. Next to the horizontal type the vertical is most commonly used, in which the tension carriage slides on the vertical guides.

It is the practice of the Dodge Co. to use a driving sheave with the diameter 40 times that of the rope, although if the rope speed is comparatively low and the drives are not in constant use, smaller sheaves may be used to advantage, the determining factor being the life of the rope.

The size of rope to be selected depends upon the diameter of sheaves, amount of power to be transmitted, and distance between centers, involving the length of rope to be handled by the tension carriage. In the Dodge American system the range is from ¾ in. to 1½ in. diameter for ordinary practice, and 1¾ to 2 in. if exceptionally large amounts of power are to be transmitted and where the conditions are favorable for the use of such large rope. As a rule the company finds better results can be obtained from 12 wraps of 1½ in. than from 9 wraps of 1¾ or 6 wraps of 2 in., although all have approximately the same capacity at a given speed. Five thousand feet a minute is adopted as the speed at which the highest efficiency is obtained.

A feature of the work of the Dodge Mfg. Co. is the changing over of belt drives to rope drives. This is done by lagging the belt wheel of the main engine with wood and turning grooves in it to carry the rope transmission. A flywheel that has been so treated is shown in one of the illustrations, the lagging being made of hard wood bolted to the flywheel rim. This method of making a rope drive wheel is comparatively inexpensive and enables the change to be made from belt to rope drive with but little inconvenience.

Points on which the Dodge Co. lays special emphasis are that the rope leaving the last groove of the driver must have a fair lead and free run to the tension sheave directly or over idlers, and that fair lead and free run from the tension sheave to the first groove of the driven wheel must be obtained, also that the rope must be parallel to itself in running toward and from the tension sheave so that the effectiveness of the tension weight will not be varied by its position. Idler sheaves are made with U grooves unless peculiar conditions require other forms, the radius of the groove being slightly larger than that of the rope, so that the rope will run free without chafing. Sheaves up to 24 ft. may be made in halves and above that are usually made in sections, as shown in one of the illustrations.

Sailor splices which make a lump in the rope should always be avoided on transmission systems, and the regular transmission splice should be used. The rope advocated by the Dodge Mfg. Co. is the Firmus Blue

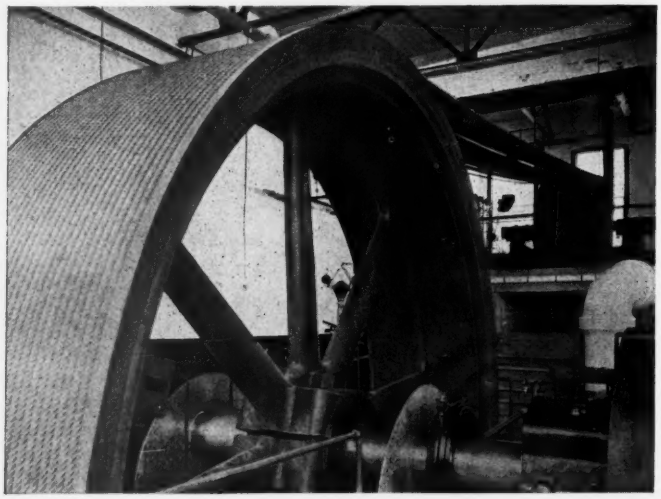
Strand, which is made with either 3 or 4 strands, as may be desired.

Rope is, of course, subject to wear, like all other apparatus, and in time frayed ends will appear. In order to protect the drive from breakdown a tell-tale is installed, so that the fingers of the tell-tale will be struck by any strand in the rope which has worked loose so that it is flying out, and if one of these fingers is struck it immediately sounds an alarm, showing on which sheave the trouble has occurred so that it is possible to locate very quickly the difficulty and make the necessary repairs.

ROPE DRIVES

Hill Clutch Co., Cleveland, O.

THERE ARE 2 systems of rope driving, the continuous or American, and the multiple or English. Of these the American System is more generally used, and



DODGE WOOD LAGGED FLYWHEEL

adapts itself to practically all conditions, whereas the application of the English System is largely controlled by the same conditions that control a belt drive.

Each American System installation presents a different problem, and the questions of efficiency, economy in first cost, and the system to be employed, must be given careful attention. Theory alone cannot be depended upon in the design of rope drives.

The Hill Clutch Co. has had eighteen years' experience in designing, building and installing American System Rope Drives under various conditions, and are thus enabled to bring to bear the results of their wide and varied experience on the solution of the most intricate rope drive problems.

ROPE TRANSMISSION

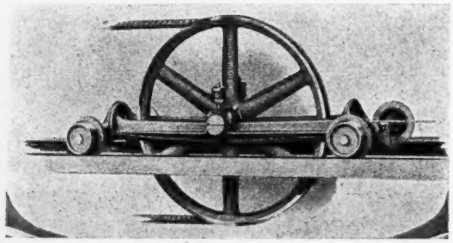
C. W. Hunt Co., West New Brighton, N. Y.

THERE IS NO doubt that the use of rope for power transmission purposes is steadily increasing, and that more attention has lately been given to the correct design of rope drives. It is this question of correct original design with the resulting satisfactory service, that will tend most to foster the growth of rope drives, and it can safely be said that with the experience now available in the design of such drives, there should be no unsatisfactory installations. Rope drives can be used in many ways about a manufacturing establishment to transmit power economically, on account of noiseless running, great flexibility, low tension on the bearings and small power losses.

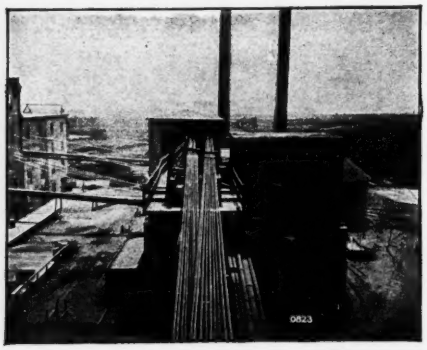
Two systems of arranging ropes on pulleys for driving purposes are generally used. First, the independent band system, in which each rope is either spliced independently or connected with a tension adjusting coupling. Second, the tension pulley or continuous system, where one continuous rope is used, wrapped around the pulleys a sufficient number of times to transmit a given power.

In the first, or independent band system, there are as many splices or couplings as there are wraps on the pulleys. In the second or continuous system, there is only one splice.

The Hunt company advocates the independent band system for transmitting large amounts of power. In this system, in case of an accident to one rope, the drive can be kept running with the others until a favorable



HILL CLUTCH CO.'S ROPE TIGHTENER FOR AMERICAN SYSTEM



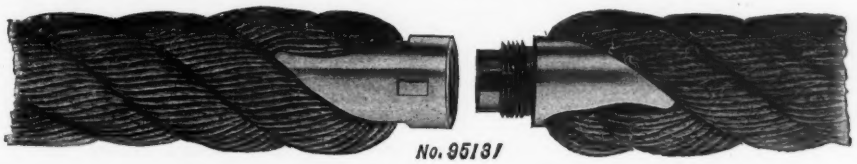
EXAMPLE OF LONG OUTDOOR DRIVE BY THE C. W. HUNT CO.

opportunity occurs to put on a new rope. With the continuous system injury to the single rope means closing down the entire drive, and everything about the works being driven comes to a standstill until the rope has been replaced or repaired.

The use of the "Hunt" tension adjusting coupling illustrated herewith in the independent band system is the best method of insuring constant operation of the plant. By means of this coupling a worn or injured rope can be replaced in a few minutes. The manufacturer furnishes rope bands to the correct length with these couplings spliced in and ready for mounting on the pulleys. Tightening is accomplished by putting turns in the rope by adjusting the Hunt coupling without removing the ropes from the pulleys.

The couplings are adapted for service in mills of every description. They are used with the same degree of satisfaction in cement mills, rolling mills, textile mills and other industries where ropes have been found highly serviceable and economical. They maintain an even tension on the ropes at all times.

Ropes are manufactured in various ways for transmission purposes. A Manila rope of selected fibre with a graphite lubrication which is very thorough and uniform, practically eliminates the internal friction caused by the sliding of the fibres upon each other when passing over the pulleys. It is this combination of strength of fibre and perfect lubrication which is so important in transmission rope. As it is often of great advantage to use rope drives out of doors, a rope treated in this manner will in a short time become thoroughly coated with the lubricant and resemble a rod of iron when running. In such condition it is practically impervious to water.



HUNT TENSION ADJUSTING COUPLING FOR MANILA ROPES

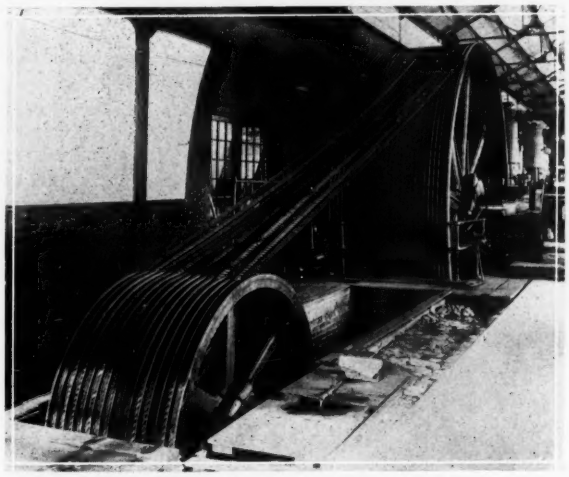
There are some situations where the continuous system of rope driving can be installed to advantage, such as in outdoor drives where contact with weather conditions has the effect of shortening and lengthening the rope. Under such circumstances, a tension weight will automatically adjust its position to correspond to this variation in length of the rope.

ROPE DRIVES

Mesta Machine Co., Pittsburg, Pa.

AN EXTENSIVELY USED method of transmitting power is by means of the rope drive, particularly for long spans, changes in the plane of rotation, or where it is necessary to distribute the power to several points.

Rope drive gives low cost of equipment and maintenance, facility for extension of power, equally good results from long or short spans and changes in the plane of rotation, and tendency to equalize the load.



MESTA ROPE DRIVE FOR THE AMERICAN STEEL AND WIRE CO. AT DONORA, PA.

Material plays a most important part in the manufacture of rope wheels, as this rim must be of sufficient strength to withstand peripheral speeds often up to 6000 ft. a minute. The practice of the Mesta Machine Co. is to use nothing but air furnace melted iron, which has a much higher tensile strength than cupola iron and is much less subject to shrinkage strains.

In order to obtain efficient results, great care must be given to the form of grooves employed so that the wheel will have sufficient grip upon the rope. Special machinery has been installed for the purpose of turning and finishing these wheels. After boring the hub the complete wheel is mounted upon a mandrel and turned in a pit lathe designed and constructed by the Mesta Machine Co. for that purpose. This pit lathe will handle a wheel 34 ft. in diameter with a 9 ft. face. This method is very much superior to doing the work on a vertical boring mill, for the reason that the wheel is free to adjust itself from any strains in the machining process and is finished perfectly round and true, where, if it were held to a boring table there would be ample opportunity for distortion. An illustration is given showing the operation of machining the grooves of a large wheel in this pit lathe.

Some of the rope driven transmission installations made by the Mesta Machine Co. are shown in the illustrations.

VOLATILE MATTER OF COAL is the title of the first bulletin to be issued by the new Federal Bureau of Mines. The authors, Horace C. Porter and F. K. Ovitz, conducted their investigations at the Pittsburg station while it was under the Technologic Branch of the Geological Survey, the work being a continuation of the fuel investigations begun several years ago at the Louisiana Purchase Exposition, St. Louis, Mo.

Quoted directly the authors say: "The investigation has already shown that the volatile content of different coals differ greatly in character. The volatile matter of the younger coals found in the West includes a large proportion of carbon dioxide, carbon monoxide and water, and a correspondingly small proportion of hydrocarbons and tarry vapors. The older bituminous coals of the Appalachian region yield volatile matter containing large amounts of tarry vapors and hydrocarbons, difficult to burn completely without considerable excess of air and a high temperature. Coal of the Western type, moreover, gives up its volatile matter more easily at moderate and low temperatures than that of the other type.

"The results show further that certain bituminous coals of the interior and Rocky mountain provinces give promise of good yields of byproducts of coking, notably ammonia and high candle power gas.

"They show also that inert, noncombustible material is present in the volatile products of different kinds of coal to an extent ranging from 1 to 15 per cent of the coal."

The bulletin will be of interest to fuel engineers, designers and builders of gas producers, gas and coke manufacturers, superintendents of power plants, railway master mechanics and those engaged in the suppression of smoke. The bulletin may be obtained by applying to the Director of the Bureau of Mines, Washington, D. C.

STEAM PIPING

IT IS NOT THE intention in this article to discuss at length methods of laying out piping systems, for each plant is a problem calling for the exercise of careful judgment on the part of the engineer to meet his special conditions, and the only guide possible is good common sense and a few general principles which are in themselves the embodiment of the common sense of those who have dealt with the subject.

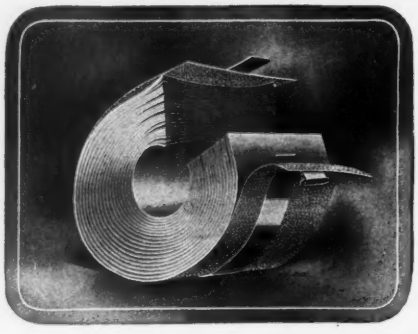
Pipe Troubles

ALL trouble with a pipe line may be traced to one of 2 sources, joints or water, and frequently joint trouble is due to water. A pipe line carefully planned, erected of good materials and with careful attention to having the joints tight in the first place and with provision for expansion, so that the joints will not be strained, might carry dry or slightly superheated steam for a century without difficulty, but with the introduction of water, which cools the bottom of the pipe while the top is kept hot with the steam current, which soaks into and disintegrates fibrous packing, which accumulates in pockets to be picked up by the steam current and banged against the fittings or valves with tremendous force, we have a trouble maker which is entitled to first honors in its special line.

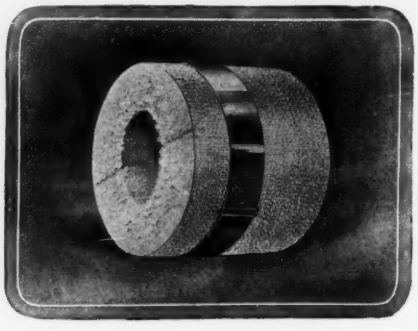
The importance of properly covering pipe is shown by the fact that covering 100 ft. of 2-in. pipe will save in a year of 300 10-hr. days a condensation of 90,000 lb. of water, equivalent to something over 5 tons of coal, and this is a direct condensation saving aside from the gain in efficiency of the machinery which the steam operates. The kind of insulation to be used depends, of course, upon the pressure and temperature of the steam to be carried, but experiments have shown that a thickness of covering greater than 2 in. does not materially assist in reducing condensation. The first inch is of the greatest importance, the second inch is of help, while beyond that further increase in the covering thickness is largely a matter of mechanical strength or of protection of the inner layers.

Tests of the different materials have shown that the efficiency of a covering is largely dependent on its ability to hold still air in a finely divided state. Hair, wool, and felt are good nonconductors, but because of their low charring temperature are not available for high-pressure steam pipe covering. Magnesia has proved on test to be the material best fitted for pipe covering and is the basis for the best coverings of all manufacturers. Next to this comes asbestos, then mineral wool and below this such materials as granulated cork, sawdust, ashes, and finally the closed air space only, the difficulty with air space being that currents are set up which increase the condensation rapidly. Considering the condensation from bare pipe as 100 per cent, the earthly insulators, such as calcite, fossil meal and asbestos will reduce the condensation to from 20 to 25 per cent, while magnesia will reduce it to approximately 17 per cent.

As examples of commercial insulation may be taken the line manufactured by the H. W. Johns-Manville Co., illustrated herewith. The Asbesto-Sponge-Felted covering for high pressure and superheated steam pipes is made from thin felt composed of best quality asbestos fiber and finely ground sponge, giving a cellular fabric. As shown by the cut it is made up in laminated form so that it meets to an exceptionally large degree the condition of holding finely divided air in a quiescent state. It is tough and flexible and can be removed and replaced any number of times.



ASBESTOS SPONGE FELTED COVERING



ASBESTOS FIRE FELT

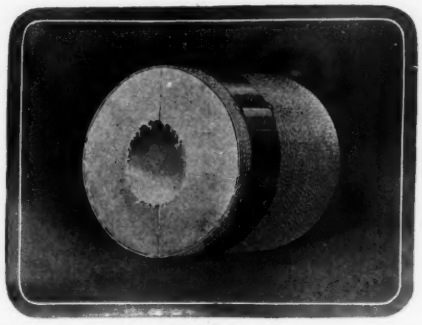
The Asbestos Fire Felt, which is also for high pressure and superheated steam, is made of asbestos fiber loosely felted together and is intended to meet the hard conditions common to shop and factory service, but has not the laminated construction of the sponge felted covering.

The Magnesia Sectional known as 85 per cent Magnesia covering is a combination of carbonate of magnesia and asbestos suitable for high pressure steam pipes, but not of as high grade as the sponge felted or the fire felt. Vitribestos is an asbestos air cell covering having high fireproof qualities and good insulating value. It is particularly adapted to service in mines and plant construction where dampness will be encountered. The Asbestocell covering is built on the arch principle with the channels running around the pipe instead of lengthwise, thus preventing effectually circulation of air along the pipe in long runs. The arch effect also prevents crushing under hard usage.

Air Cell pipe covering is made for medium steam pressure; it is a light covering of corrugated asbestos paper with channels running lengthwise of the pipe, used largely for low pressure steam and hot water heating. Molded asbestos for medium pressure pipes

is composed of asbestos fiber and other fireproof materials and is to be used only where a low-priced covering is demanded.

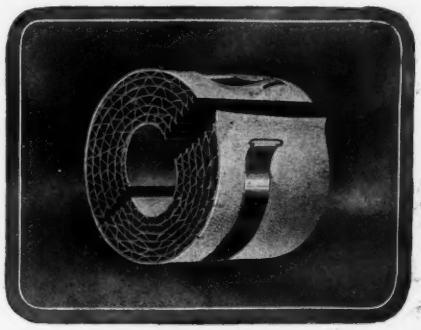
Even when a system is well covered as to the pipe lengths, it is frequent to see the flange joints projecting with no insulation on them whatever, spite of the fact that one good sized flange joint with its bolt heads will furnish as much radiating surface as several feet of piping. It is, of course, some more work to cover a joint than to cover a straight length of pipe, but covering the pipe and leaving the joints, either flanged or screwed, without covering is a penny wise



MAGNESIA SECTIONAL COVERING

and pound foolish policy and with the many makes of special joint covering now available there is no need of such an oversight or neglect.

Even though the covering must be made of a plastic material, the saving by covering the joints is worth while, not only because of the reduction in condensation but also because condensation at these joints takes place at the worst possible location. Water can here get at corners and crannies where it may settle and corrode the metal and in the case of a flange joint it



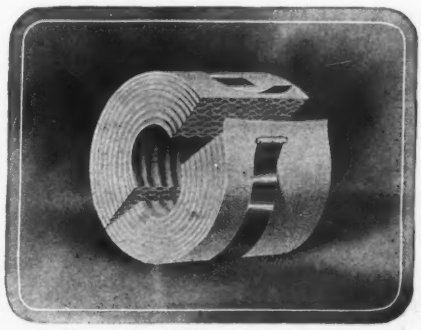
VITRIBESTOS AIR CELL INSULATION

may here do its most insidious work in breaking down the system, by seeping up around the packing and preparing things for a possible blow-out.

The same argument applies to valves and other apparatus in the line, with the added point that a valve for its own sake, regardless of the condensation effect in the system, should be protected as much as possible against rapid expansion and contraction. The careful covering of all piping, fittings and accessory apparatus is a point which will well repay the engineer, not only because of the saving in his fuel bill but also by the lessening of his labor in keeping the plant in shape.

Expansion.

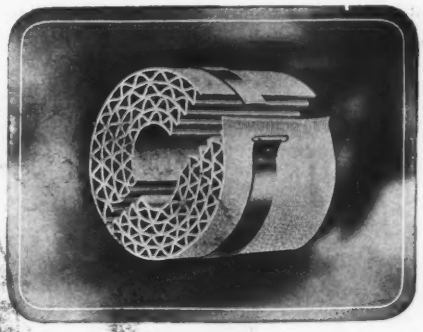
IN a line of steam piping the temperature will range from that of the atmosphere at any where from 10 deg. below zero up to the temperature of steam at or above the pressure in the pipe, depending on whether the steam is superheated or not, and this temperature will run as high as 500 to 600 deg. in many plants. It



ASBESTOCELL ARCH FORM COVERING

becomes necessary, therefore, to provide for the expansion and contraction of piping by this amount.

In general 4 methods are used for taking care of the come and go due to expansion: One a swing joint which may be composed of pipe fittings and nipples if the amount to be taken care of is not great or for a larger amount of movement made with a regular ground joint. The second is a slip joint made with a stuffing box and gland, the outer member being usually of steel or iron and the inner tube of brass; the third is a corrugated tube or diaphragm which by its flexibility takes up the movement of the pipe and the



AIR CELL COVERING FOR MEDIUM PRESSURES

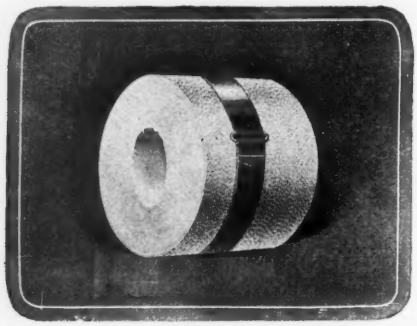
fourth is some form of bend, either a quarter bend, U, circle or ogee, according to the circumstances and the judgment of the designing engineer.

To determine the amount of expansion which must be provided for, we must know the temperature range and then we have the coefficient of expansion for cast iron is 0.0000062, for wrought iron 0.0000066, and for steel of the quality used in steam piping practically the same as for wrought iron. This coefficient is not, however, a constant but varies from the values given between 32 and 100 deg., up to a value of 0.00000814 for wrought iron at 500 deg. This coefficient of expansion is the part of its own length by which a pipe expands for each degree F. rise in temperature and the rule for finding the total expansion of a length of pipe is: Multiply the length of pipe in inches by the degrees increase in temperature and by the coefficient of

expansion as given above. The method of variation of this coefficient for cast iron is as follows:

100 degrees	0.00000600
150 degrees	0.00000612
200 degrees	0.00000626
250 degrees	0.00000642
300 degrees	0.00000660
400 degrees	0.00000700
500 degrees	0.00000740

The expansion for each 100 ft. in length for different degrees F. is shown in the practical table on



MOLDED ASBESTOS COVERING FOR HEATING PIPES

this subject, and the expansion for any length between 2 temperatures may be found by taking the difference in length at these 2 temperatures, as given in the table, dividing by 100 and multiplying by the length of the pipe in feet. It will be noted that the coefficient for wrought iron is 1.1 times that for cast iron and for brass it is 1.6 that for cast iron.

Bends

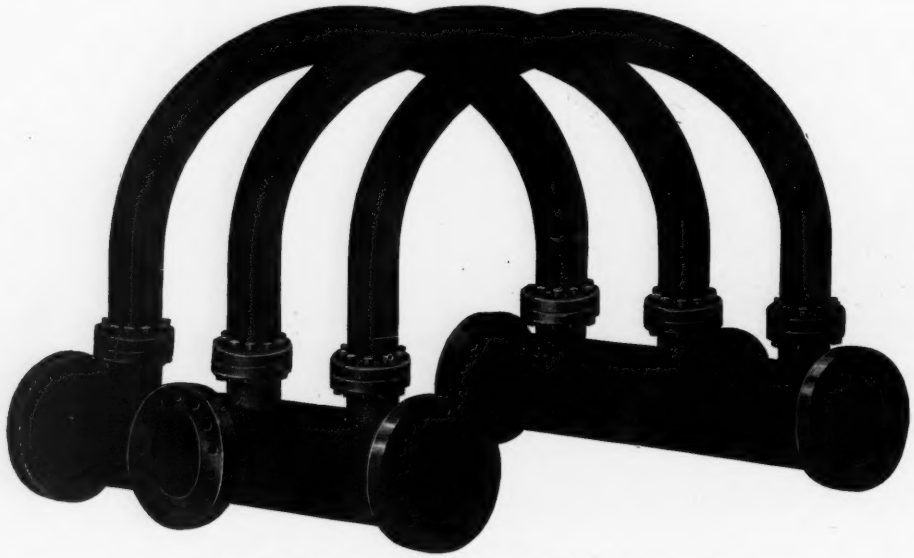
As a basis for expansion bends, the practice of the Best Mfg. Co. of Pittsburg which makes a specialty of such work may be taken as representing good usage.

Radii for Expansion Bends

Pipe Size.	Radius, In.	Straight Pipe Required Each End, In.
⅛	3	¾
¼	3½	1
⅜	4	1¼
½	5	1½
¾	6	1¾
1	7	2¼
1¼	8	2½
1½	10	2¾
2	12	3
2½	14	3½
3	18	4
3½	20	4½
4	24	5
4½	26	5½
5	30	6
6	36	6½
7	4 ft.	7
8	4 ft. 6 in.	8
9	5 ft.	10
10	5 ft. 6 in.	12
11	6 ft.	13
12	7 ft. 6 in.	14
14	8 ft.	18
15	8 ft. 6 in.	20
16	10 ft.	22
18	12 ft.	24
20	14 ft.	24
22	16 ft.	24
24	18 ft.	24

Drainage

AS already explained, water is one of the chief sources of difficulty in a piping system and the greatest precaution should, therefore, be taken to make sure that this water will be removed as fast as it enters the system. While condensation is the source



EXAMPLE OF EXPANSION BEND FROM BEST MFG. CO.

Smaller radii may be used, but will result in a more rigid bend, and possibly necessitate the use of extra heavy pipe which makes the bend still more rigid, defeating the object for which it is used.

of a considerable accumulation of water, the great difficulty in providing drainage is to take care of the sudden rushes which come from priming in the boiler or from the accidental opening of a valve which per-

mits the sweeping up of accumulated condensation from the pipe in front of the valve. Provision must, however, be made at reasonable intervals for just these sudden rushes because they are sure to occur in every plant at more or less frequent intervals.

All pipe lines should be pitched from ¼ to ½ in. in each 10 ft. in the direction of flow of the steam, and at the dead end a drip pocket or drip pipe should be provided.

An exception to this is the main header into which boiler outlets and engine feeders are connected transversely. In such a case the flow may be in either direction along this header and it should be set horizontal and provided with a drip pocket at either end so that no matter in which direction the steam is flowing the condensation will be carried with it and properly removed. In a case of this kind a very small drip pocket or even a good size pipe without a pocket may suffice, as there is no tendency for the current of water to carry by the end of the drip pipe.

EXPANSION OF PIPES 100 FT. LONG

TEMP. DEG. F.	INCREASE IN LENGTH ABOVE 100 FT.			
	CAST IRON IN.	WROT IRON IN.	STEEL IN.	COPPER AND BRASS
0	0	0	0	0
50	0.36	0.40	0.38	0.57
100	0.72	0.79	0.76	1.14
125	0.88	0.97	0.92	1.40
150	1.10	1.21	1.15	1.75
175	1.28	1.41	1.34	2.04
200	1.50	1.65	1.57	2.38
225	1.70	1.87	1.78	2.70
250	1.90	2.09	1.99	3.02
275	2.15	2.36	2.26	3.42
300	2.35	2.58	2.47	3.74
325	2.60	2.86	2.73	4.13
350	2.80	3.08	2.94	4.45
375	3.15	3.46	3.31	5.01
400	3.30	3.63	3.46	5.24
425	3.68	4.05	3.86	5.85
450	3.89	4.28	4.08	6.18
475	4.20	4.62	4.41	6.68
500	4.45	4.90	4.67	7.06
525	4.75	5.22	4.99	7.55
550	5.05	5.55	5.30	8.03
575	5.36	5.90	5.63	8.52
600	5.70	6.26	5.98	9.06
625	6.05	6.65	6.35	8.62
650	6.40	7.05	6.71	10.18
675	6.78	7.46	7.12	10.78
700	7.15	7.86	7.50	11.37
725	7.58	8.33	7.96	12.06
750	7.96	8.75	8.36	12.66
775	8.41	9.26	8.84	13.38
800	8.87	9.76	9.31	14.10

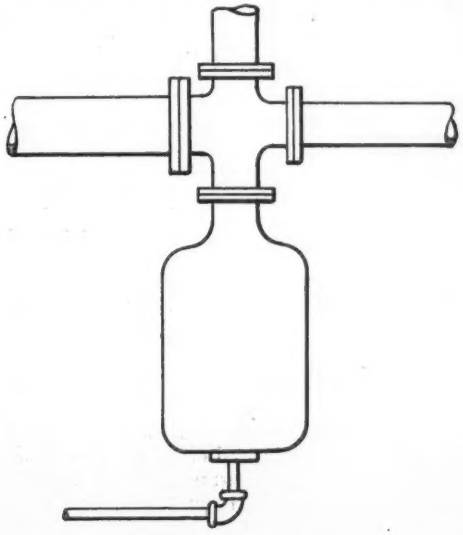
Branches should be taken out of the top with a valve placed at the highest point in the line, so that when the branch is shut off condensation will drain both ways from the valve, thus avoiding the accumulation of water in the branch.

Final removal of suspended moisture and of condensation which accumulates in the pipe is accomplished by the use of a separator which should be placed as near to the engine as possible.

In the selection of a separator there is the same difficulty encountered as in providing the piping system. In order to get efficient separating action it is necessary to slow down the steam, but to use a large separator increases the radiating surface, thereby increasing condensation. The best solution of this problem seems, therefore, to use a separator having large area through the steam section and having comparatively small storage capacity for water, but drained by a large drip pipe, controlled by a trap with ample capacity so that the separator will be kept cleared of water. The different types of separators in common use for steam piping are illustrated and described in another part of the paper, also the different types of traps and their method of action.

CRANE CO.'S SLIP EXPANSION JOINT

In locating the trap it should be placed so that it will get easy flow of water from the drip pocket or separator which it serves and it is better as a usual thing to install a trap for each drip line rather than to run a number of drip lines into a single trap. If, however, there are a number of small drips near together it may be desirable to run them all into a good



USE OF DRIP POCKET

sized receiver and drain this receiver by means of a large trap. While it is desirable to use as much auxiliary apparatus as necessary for the purposes of the plant, it should be remembered that the more pieces of apparatus used and the more joints made in the steam piping the more places there are for possible trouble.

Steam Control

THIS is, of course, by means of valves and in the choice of valves and their location more than in anything else is shown the good judgment of the engineer who lays out a piping system. Usually, if the principle of simplicity be made the governing feature in a piping system, the method of running the piping will be reasonably clear, but the foreseeing of possible trouble or of necessary emergency combinations and

placing of valves and occasional crossovers to take care of these emergencies will require the most careful study.

Where it is necessary to reduce the pressure of steam a reducing valve of some sort must be provided. Depending upon the reduction of pressure by throttling with an ordinary gate or globe valve is not safe, for the slightest change in steam required on the low-pressure side will produce an accumulation of pressure there which may be dangerous to the low-pressure apparatus.

Good practice now provides for automatic stop valves so installed that in case of a rupture in the steam main the boiler will be shut off, thus preventing

WESTERN EXPANSION PIPE HANGER

filling the plant with steam, or in case of fall of pressure in the boiler the steam will be prevented from backing up from the header into the boiler. Even with this provision a good stop valve should be used on each boiler, so that when cleaning or repairs are necessary there may be absolute certainty that steam cannot get in to endanger the lives of those working in the boiler.

Different types of valves are shown in the section devoted to that subject in all classes. The choice of a valve must rest on the judgment of the engineer and the fitness of the valve to meet the special conditions in each part of the system. Frequently it is the case that different types of valves should be used in different parts of the system and the splitting of an order ought not to cause an engineer to hesitate for a moment where good engineering demands it.

Determination of Pipe Size

BRIEF discussion of this has already been taken up, the opposing requirements of low friction and small condensation being mentioned. To get exactly the most economical size of piping is a problem requiring a good deal of cut and try figuring and ordinarily the size is determined by the permissible drop in pressure, since the variation of condensation within limits set by permissible drop is not a very large item. This allowable drop depends on the velocity of flow of the steam, the size of pipe and the length of the run, counting valves and fittings as their equivalent in length of straight pipe, according to the table already given.

Flow of steam in pipes is not so simple a proposition as at first sight appears and the basis for this flow has been figured usually by the same formulas that apply to the flow of water. Evidently the same conditions exist, only that the friction between the pipe and the steam is much less in proportion than the friction between the pipe and water. The most commonly used formula is a modification of that proposed by Babcock in "Steam" which made this flow depend upon the square root of the density of the steam, the square root of the drop in pressure, the square root of the 5th power of the diameter, and inversely upon the square root of the length.

The rule, modified by Kent, for finding the weight of steam passing in a pipe becomes as follows: Multiply

TABLE OF PIPES OF EQUAL STEAM FLOW CAPACITY

Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Dia.
½		2.27	4.88	15.8	31.7	52.9	96.9	205	377	620	918	1,292	1,767	2,488	3,014	3,786	4,904	5,927	7,321	8,535	9,717	½
¾	2.60		2.05	6.97	14.0	23.3	42.5	90.4	166	273	405	569	779	1,096	1,328	1,668	2,161	2,615	3,226	3,761	4,282	¾
1	7.55	2.90		3.45	6.82	11.4	20.9	44.1	81.1	133	198	278	380	536	649	815	1,070	1,263	1,576	1,837	2,092	1
1½	24.2	9.30	3.20		1.26	3.34	6.13	13.0	23.8	39.2	58.1	81.7	112	157	190	239	310	375	463	539	614	1½
2	54.8	21.0	7.25	2.26		1.67	3.06	6.47	11.9	19.6	29.0	40.8	55.8	78.5	95.1	119	155	187	231	269	307	2
2½	102	39.4	13.6	4.23	1.87		1.83	3.87	7.12	11.7	17.4	24.4	33.4	47.0	56.9	71.5	92.6	112	138	161	184	2½
3	170	65.4	22.6	7.03	3.11	1.66		2.12	3.89	6.39	9.48	13.3	20.9	23.7	31.2	39.1	50.6	61.1	75.5	88.0	100	3
4	376	144	49.8	15.5	6.87	3.67	2.21		1.84	3.02	4.48	6.30	8.61	12.1	14.7	18.5	23.9	28.9	35.7	41.6	47.4	4
5	686	263	90.9	28.3	12.5	6.70	4.03	1.83		1.65	2.44	3.43	4.69	6.60	8.00	10.0	13.0	15.7	19.4	22.6	25.8	5
6	1,116	429	148	46.0	20.4	10.9	6.56	2.97	1.63		1.48	2.09	2.85	4.02	4.86	6.11	7.91	9.56	11.8	13.8	15.6	6
7	1,707	656	226	70.5	31.2	16.6	10.0	4.54	2.49	1.51		1.41	1.93	2.71	3.28	4.12	5.34	6.45	7.97	9.31	10.6	7
8	2,435	936	322	101	44.5	23.8	14.3	6.48	3.54	2.18	1.43		1.35	1.93	2.33	2.92	3.79	4.57	5.67	6.60	7.52	8
9	3,335	1,281	440	137	60.8	32.5	19.5	8.85	4.85	2.98	1.95	1.37		1.41	1.71	2.14	2.77	3.35	4.14	4.83	5.50	9
10	4,393	1,688	582	181	80.4	42.9	25.8	11.7	6.40	3.93	2.57	1.80	1.32		1.21	1 52	1.97	2.38	2.94	3.43	3.91	10
11	5,642	2,168	747	233	103	55.1	33.1	15.0	8.22	5.05	3.31	2.32	1.70	1.28		1.26	1.63	1.88	2.43	2.83	3.22	11
12	7,087	2,723	938	293	129	69.2	41.6	18.8	10.3	6.34	4.15	2.91	2.13	1.61	1.26		1.30	1.57	1.93	2.26	2.58	12
13	8,657	3,326	1,146	358	158	84.5	50.7	23.0	12.6	7.75	5.07	3.56	2.60	1.98	1.53	1.22		1.21	1.49	1.74	1.98	13
14	10,600	4,070	1,403	438	193	103	62.2	28.2	15.4	9.48	6.21	4.35	3.18	2.41	1.88	1.50	1.22		1.24	1.44	1.64	14
15	12,824	4,927	1,698	530	234	125	75.3	34.1	18.7	11.5	7.52	5.27	3.85	2.92	2.27	1.81	1.48	1.21		1.17	1.35	15
16	14,978	5,758	1,984	619	274	146	88.0	39.9	21.8	13.4	8.78	6.15	4.51	3.41	2.66	2.12	1.73	1.42	1.18		1.14	16
17	17,537	6,738	2,322	724	320	171	103	46.6	25.6	15.7	10.3	7.20	5.27	3.99	3.11	2.47	2.03	1.66	1.37	1.17		
18	20,327	7,810	2,691	840	371	198	119	54.1	29.6	18.2	11.9	8.35	6.11	4.63	3.60	2.87	2.35	1.92	1.59	1.36	1.16	
20	26,676	10,249	3,532	1,102	487	260	157	70.9	38.9	23.9	15.6	10.9	8.02	6.07	4.73	3.76	3.08	2.52	2.08	1.78	1.52	
24	42,624	16,376	5,644	1,761	778	416	250	113	62.1	38.2	25.0	17.5	12.8	9.70	7.55	6.01	4.92	4.02	3.32	2.84	2.43	
30	75,453	28,990	9,990	3,117	1,378	736	443	201	110	67.6	44.2	31.0	22.7	17.2	13.4	10.7	8.72	7.14	5.88	5.03	4.30	
36	120,100	46,143	15,902	4,961	2,193	1,172	705	319	175	108	70.4	49.3	36.1	27.3	21.3	16.9	13.9	11.3	9.37	8.01	6.85	
42	177,724	68,282	23,531	7,341	3,245	1,734	1,044	473	259	159	104	73.0	53.4	40.5	31.5	25.1	20.5	16.8	13.9	11.9	10.1	
48	249,351	95,818	33,020	10,301	4,554	2,434	1,465	663	363	223	146	102	75.0	56.8	44.2	35.2	28.8	23.5	19.4	16.6	14.2	
Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	

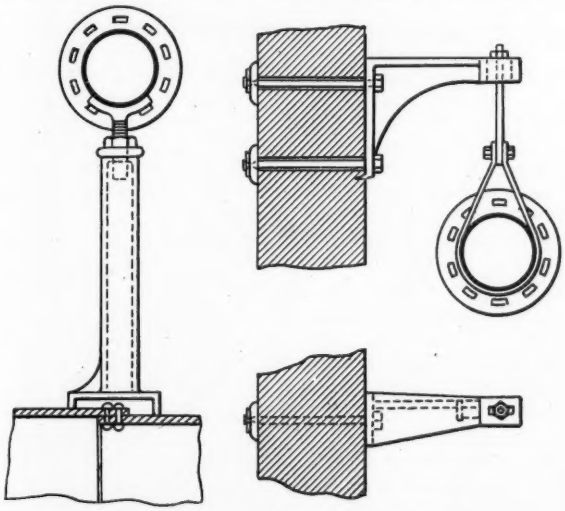
the drop in pressure permissible by the 5th power of the internal diameter of the pipe and by the weight per cubic foot of steam at the initial pressure. Divide this by the length of the pipe expressed in feet; extract the square root of the quotient and multiply by a constant which varies with the diameter of pipe and is as follows:

For ½-in. pipe, 36.8.
For 1-in. pipe, 45.3.
For 2-in. pipe, 52.7.
For 3-in. pipe, 56.1.
For 4-in. pipe, 57.8.
For 5-in. pipe, 58.4.
For 6-in. pipe, 59.5.
For 8-in. pipe, 60.7.
For 10-in. pipe, 61.8.
For 12-in. pipe, 62.1.
For 14-in. pipe, 62.3.
For 16-in. pipe, 62.6.
For 18-in. pipe, 62.7.
For 20-in. pipe, 62.9.
For 22-in. pipe, 63.2.
For 24-in. pipe, 63.2.

In figuring the size of a main pipe to take care of a number of branches it is not sufficient to consider simply the equality of areas, since the flow varies with the drop in pressure and the drop in pressue is much larger for a small pipe than for a big one. The rule for this flow has already been given and it is seen that it varies in proportion to the square root of the 5th power of the diameter. It is, therefore, a decidedly awkward matter

to compute this equality, and G. H. Babcock has arranged the table herewith, based on the relation as explained. The values above the diagonal break are for actual internal diameters of standard pipe as shown in the practical tables, and the values below the diagonal break are for pipes with the actual internal diameter shown.

To use this table for actual pipe, suppose that it is required to find a main pipe which will take care of a 4-in., a 6-in. and an 8-in. branch. It is necessary to reduce these all to a common size. Taking the smallest size we find that in the 6-in. column, reading from the top, opposite 4 in the left hand column is found 3.02, that is, a 6-in. pipe is equivalent to 3.02 4-in. pipes; likewise an 8-in. pipe is equal to 6.30 4-in. pipes. The sum



PIPE PILLAR AND SLING SUSPENSION

of these is 3.02 plus 6.30 plus 1, equals 10.32 4-in. pipes. Reading along the line opposite 4 in the left-hand column, we find that a 10-in. pipe is equal to 12.1 4-in. pipes, while a 9-in. is equal to 8.61 4-in. pipes. About half way between these would do. If it is permissible to allow a little extra drop or if the main pipe is very short, then the 9-in. pipe could be used. If, on the other hand, the main pipe is long, then the 10-in. pipe should be used.

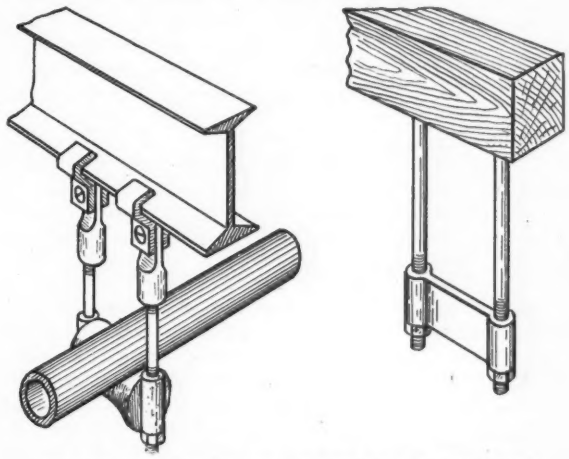
Installation

IN THE installation of piping, the chief points to be looked out for are that the pipe shall be properly supported, that it shall have proper provision for expansion and shall be anchored so that the expansion goes to the proper point, that the pipe comes in line so that the joints are fair and true, and that these joints are properly put up so that there will be no trouble from leaks to contend with after the piping is in place.

In providing supports, the method used is that of a pillar suport from below, bracket support from side walls, or a sling suspension of some sort from overhead. In any form, the piping while being held so that it cannot get away must be free to move both lengthwise and sidewise, as lengthwise motion will be caused by expansion of the piping itself, while sidewise motion will be caused by the expansion of the branches.

What form of support shall be used is generally determined by the surroundings, but it is well to keep in mind that the sling support allows greater tendency to vibration than does the bracket support, also that the roller bearing, while it permits of elongation and contraction, also increases the tendency to vibration; it is quite as satisfactory to provide a free sliding support which will permit the pipes to come and go while at the same time putting a damper on the tendency for the pipes to vibrate.

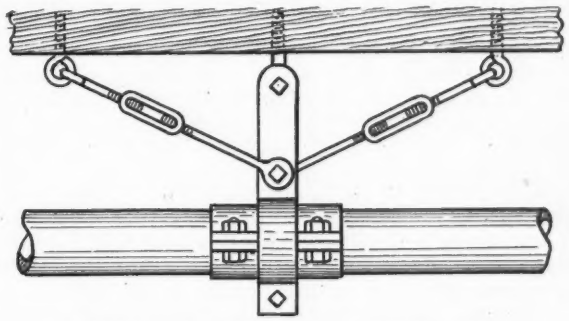
For large piping, especially where high temperature steam is to be used, it is good policy to have some form



METHOD OF SUPPORT BY BRACKETS AND COLUMNS

of saddle which shall conform to the shape of the pipe so that the support will not be along a narrow line at the bottom. With such support, the saddle should be arranged so that it can slide on the bearing below it as well as permitting the pipe to slide in the saddle.

As to frequency of supports, this is determined more by the requirements for taking off branches on the line and for preventing vibration than by the strength of the pipe itself. Occasionally in very long transmission lines it may be necessary to see that supports are placed sufficiently often to prevent sag of the pipe, or else that some form of trussing by tension rods and a strut is used.



A METHOD OF ANCHORING A SLUNG PIPE

Care should be taken in arranging supports that no weight is carried on any valve as this will produce strain on the valve and probably leakage after a short time. Also in the arrangement of branches, a length of pipe should not be allowed to carry the weight of a vertical riser without a solid support near to the point where the riser enters the main pipe.

To prevent vibration in a piping system the methods commonly adopted are the tying of the pipe to a wall or foundation or the use of an anchor support which consists of straps binding the pipe fast to a rigid support. Frequently where the vibration is due to the action of an engine or a number of engines which set up motion of the pipe practically in unison with the stroke of the en-

gine, relief will be had by the introduction of a large receiver near the engine to form a supply reservoir for the steam. This receiver may well be made a part of a separator which takes out moisture, thus serving a double purpose.

For making bends in smaller piping, various methods may be used, one of the simplest being insertion of the end of pipe through a hole slightly larger in diameter than the pipe in a thick flange and springing the end of the pipe as much as may be necessary. In using this method it is necessary to make the amount of spring at each point in the pipe slight, as otherwise there will be a flattening of the pipe.

By making a number of small bends at a short distance apart a considerable offset can be secured without materially changing the circular form of the pipe, but if any considerable bend is required, a form should be made up to the curvature to which it is desired to bend the pipe and, while one end of the pipe is held fast, the pipe should be bent around this form. If the curvature is sharp, it is best to fill the pipe with perfectly dry sand and heat it to red heat before bending in order to avoid making an oval spot in the pipe and also to prevent the tendency to open up the seam. In making such a bend the seam should always be kept on the inside of the curve if possible. Bends in larger pipe must, of course, be made at shops where there are special facilities for this work.

In cutting and threading pipe, care should be taken first that there is no reduction of the inside diameter of the pipe and second that thread is so cut that it will give a reasonable amount of make-up and yet not make up too far. The wheel cutter always tends to make a burr on the inside of the pipe and this should be reamed out carefully so as to leave the end of the pipe of full internal diameter. The thread should then be cut so that the perfect thread will have the length as shown in the table of pipe sizes, but this thread should not be carried farther than this point because, if it is, either the joint will not be tight or the pipe will make into the fitting too far and throw out the alinement of the pipe or possibly in the case of a coupling or tee cause interference between the pipe ends.

In making up a pipe joint, it should be screwed securely into place but not forced more than is necessary for a good joint as such forcing produces a heavy strain on the fittings and likelihood of cracking when steam is turned on. Also in case of a valve it is likely to produce distortion of the valve body which may cause leakage when the valve is put into service. In screwing on a valve the wrench or tongs should always be put on the end of the valve next to the pipe as a twist which is carried through the body of the valve is likely to produce permanent distortion which will cause a leak.

In making up the final joint on a line, a union, either of the screw or flange form, is always to be preferred rather than a right and left coupling. Where it is absolutely necessary to use a right and left care should be taken that the fitting makes up onto both ends of the pipe so as to give a tight joint. This can be insured by screwing the fitting on to one end of the pipe and then the other by hand, noting the number of turns required in each case. The end which takes the greater number of turns should then be entered by that number of threads before the second end is joined into the fitting.

Details

THE question of wrought-iron versus steel pipe sometimes comes up and here it may well be said that as a rule the steel piping will be found quite as satisfactory as the wrought iron except in the matter of cutting threads. A sharp die will give a good thread on a steel pipe but a dull die will not, even though on a wrought-iron pipe it may work reasonably well. So far as strength and durability are concerned, the 2 are on an equality. The difference between them is largely one of texture of material, the steel being a finer grain and without the fibrous appearance which the wrought iron has in the fracture. It is this fibrous nature which enables wrought iron threads to stick together, where the steel thread is sheared off and stripped by the dull die.

In choosing material for highly superheated steam construction, it is necessary to avoid cast-iron fittings and bronze for valves and valve fittings. Steel castings must be used for the fittings, and for the valves steel bodies and nickel steel seats and disks, also the stems should be made of nickel steel.

As an example of good construction, the following details from a set of specifications of the Best Mfg. Co. will serve. For pressures 125 lb. or under, saturated steam, use iron body, bronze mounted gate or globe valves with outside screw and yoke and for small sizes, screwed end, globe, gate or angle valves. Above 125 lb. use extra heavy valves, the gate valves 12-in. and larger to be bypassed, and for over 150 lb. 8-in. and larger to be bypassed and to have rolled steel or bronze stems. Iron body globe valves to be medium heavy, and for over 150 lb. to have bronze stems. Smaller sizes to be extra heavy all brass with screwed ends.

For superheated steam, not over 160 lb. and 100 deg. superheat, use extra heavy iron body pattern valves of semi-steel, 8-in. and larger bypassed, with rolled steel or bronze stems; globe valves to be semi-steel, and brass valves extra heavy. For higher temperatures use valves of semi-steel or cast steel with nickel steel mountings and rolled steel or nickel steel stems. Gate valves are recommended for all places except throttles where globes are preferred.

For fittings on 125 lb. or less use standard cast iron and over 125 lb. use extra heavy cast iron pattern. For superheat up to the low limit given use extra heavy semi-steel, and above that semi-steel or cast steel depending on the temperature, 2½-in. or larger to be flanged in all cases, and 2-in. and under screwed with sufficient unions to allow easy disconnection.

Pipe to be standard for 6-in. and smaller; from 7-in. to 12-in. to be of specified weight and inside diameter, with allowance of 5 per cent variation either way; these values approximately as given in the table of standard pipe sizes. For sizes above 12-in. use outside diameter pipe of full weight, not less than ⅜-in. thick.

Flanges for saturated steam at 125 lb. or less to be standard cast iron. For pressure over 125 lb. use extra heavy cast iron; and for superheated steam use semi-steel or cast steel for low temperatures and rolled steel for high temperatures. Flanges for 12-in. pipe and smaller at 125 lb. and under to be screwed on and larger to be shrunk on and rolled. Above 125 lb. 6-in. and larger to be Van Stone joint and under 6-in. to be preferably welded.

For saturated steam use first quality soft packing or corrugated copper gaskets, and for superheated use soft steel or copper corrugated with asbestos rings or a fibrous packing.

Bolts to have square heads and hexagon nuts finished under the heads and with bearing on flange faced off.

For drip piping the same specifications apply as for steam pipe.

Where Van Stone joints are used, the pipe must be steel as wrought iron cannot be worked.

AMERICAN SEPARATOR

American District Steam Co., Lockport, N. Y.

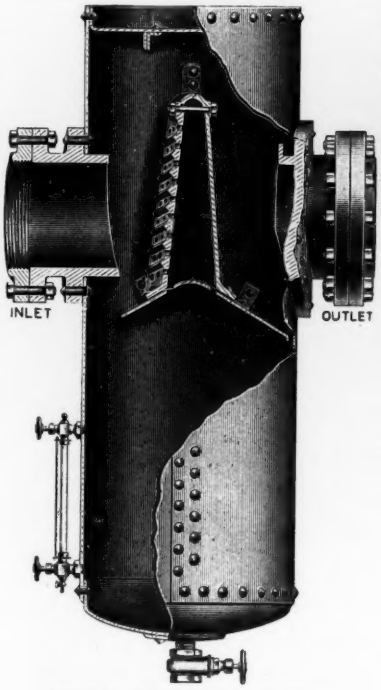
THE MODEL E type American steam separator is manufactured to meet requirements of both high and low pressure steam systems. The separation of oil or water is performed by an inclined corrugated baffle plate placed just in front of the inlet, which throws the steam upward at an angle, the moisture being caught by the corrugations and conducted to the lower edge of the baffle where it drains to the water space in the lower part of the separator. Around the outlet is a projecting lip which catches the water thrown to the walls of the separator by the reversal of steam as it enters the outlet pipe, and this condensation drains downward also to the water space, where it is carried away.

AUSTIN SEPARATORS

Austin Separator Co., Detroit, Mich.

AUSTIN STEAM AND OIL separators are designed for all conditions of installation, including vertical, horizontal, angle and special types, in both iron and steel.

These separators are constructed with great internal areas permitting proper expansion of the steam in course of separation and providing great capacity for reception of separated moisture, oil and impurities from the steam.



AUSTIN HORIZONTAL STEEL RECEIVER SEPARATOR

Deeply corrugated baffle plates scientifically and carefully constructed, serve to eliminate water and oil, which in turn is drained down the corrugations into the receiver, the steam itself passing over and around the baffle and out in a highly efficient state for the operation of steam engines, or in exhaust steam, thoroughly purified so that the condensation is rendered distilled water fit for boiler feed or many other economical purposes.

A highly competent engineering department, exceedingly careful manufacture, with sufficient areas and many other equally important conditions involved, have served to render these separators standard.

THE BARAGWANATH SEPARATOR

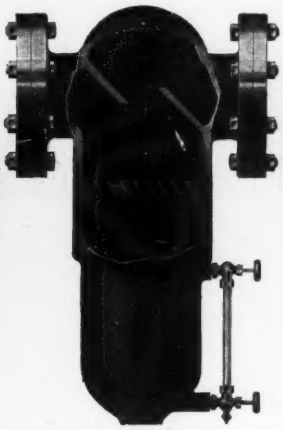
Wm. Baragwanath & Son, Chicago

THREE TYPES, vertical, horizontal and angle, are made, the vertical type being chosen for description. This is arranged for downward flow of steam and has perforated baffle sheets which nowhere are less than 4 times, while the separator itself has 12 to 16 times the area of the steam pipe. Condensation is caught on the plates and carried to the outer circumference of the separator where it drains down to the bottom and is trapped away. The steam passes through the perforations and then to the outlet pipe in the center of the bottom.

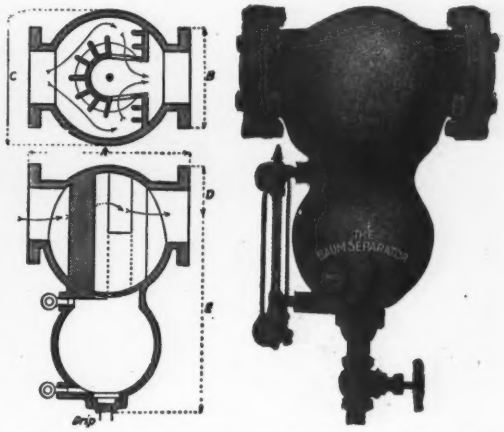
BAUM STEAM SEPARATORS

Hershey Machine & Fdry. Co., Manheim, Pa.

IN THE BAUM separator a star shaped baffle plate engages the steam as it enters the apparatus and by a series of reversals gathers the moisture from the steam upon the plates of the baffle and conducts it to the lower part of the separator where it is entirely out of contact with the steam. The Standard separator as seen in cross section and in exterior view is of double spherical form, equipped with water gauge and drip from the receiving chamber. It is designed for pressure up to 250 lb. The Baum separators are also made in steel shell type for the larger sizes.



TYPE C LIBERTY-GREENAWAY SEPARATOR FOR HORIZONTAL LINES



THE BAUM SEPARATOR, SECTION AND ELEVATION

LIBERTY-GREENAWAY SEPARATORS

Elliott Co., Pittsburgh, Pa.

THE TYPE A vertical separator, which is designed for removing the entrained water from steam, consists of a cylindrical casting containing an inverted V extending entirely across the interior of the chamber covering the outlet. Steam enters at the top and strikes the inverted V and is divided into 2 streams, causing the steam and water to flow over its surface and throwing the water out of the steam into the water chamber below. The steam must then pass under the edge of the inverted V before it can enter the central pipe to be discharged. Around this central pipe are conical flanges to prevent the upward creeping of the separated water.

In the type C horizontal separator the direction of the flow of the steam is from left to right, and the principle upon which this type produces the desired results

is shown so clearly, as to require no extensive description. However, the steam has not only a whipping action in passing under the left hand baffle plate at the inlet, but is also caused by this deflection to come in contact with the inclined bars, which have a scrubbing action on it, and in addition serve to catch the entrainment, which passes in the water chamber entirely out of the course of the steam, and is discharged into the drip pipe at the bottom.

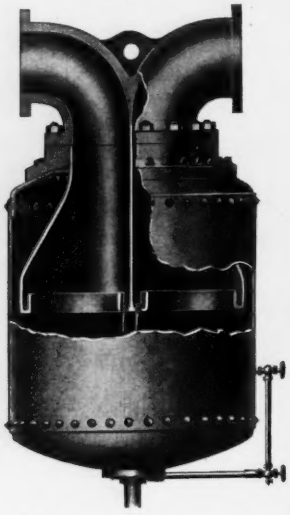
HOPPES SEPARATOR

The Hoppes Mfg. Co., Springfield, Ohio

THESE SEPARATORS ARE DESIGNED to allow the steam to expand gradually into a large chamber where water is intercepted, and the steam is then gradually reduced to the capacity of the steam pipes.

To prevent entrainment from being sprayed into the steam chamber and increasing the moisture of the steam, it is intercepted at both outlet and inlet by troughs partly filled with water, the action being illustrated by the shadow view of the horizontal type shown herewith. Steam entering the inlet plunges downward

HOPPES HORIZONTAL TYPE SEPARATOR



THE HOPPES STEEL SHELL RECEIVER SEPARATOR

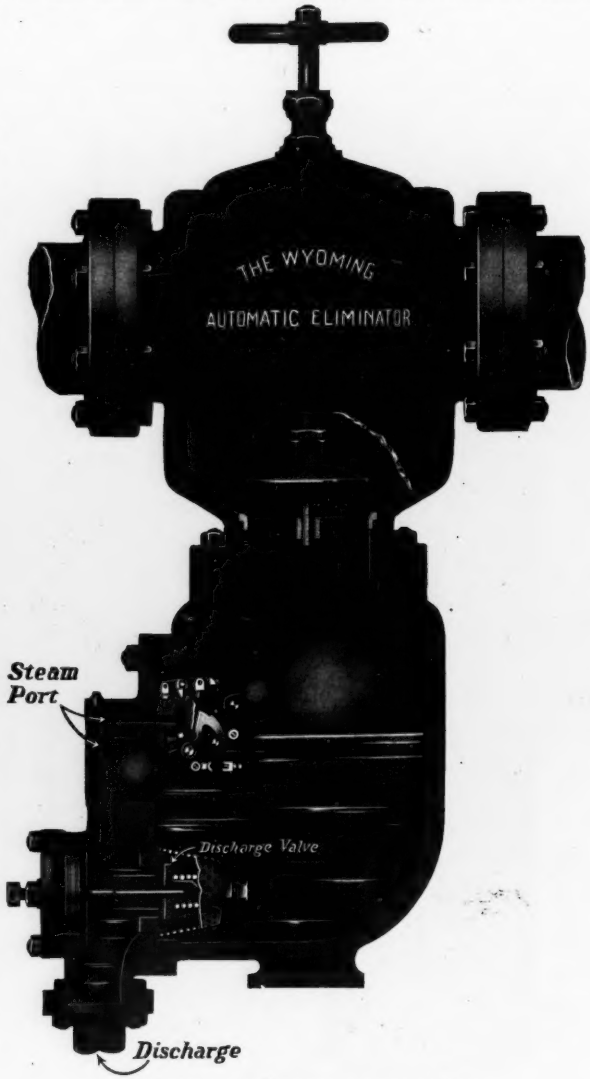
around the center baffle, the water being caught by the trough which surrounds the inlet. The steam then turns and ascends to the outlet passage, gradually contracting in volume, and water dropped from the steam during this contraction is caught in a second trough which surrounds the outlet passage. Excess water is carried by pipes from the troughs to the bottom of the separator from which it is trapped away. The same principle is applied in the steel type of receiver separator for either vertical or horizontal piping. A novelty in the matter of separators is the right angle shell type in which either the side or top connection may be used for the inlet according to the conditions of the piping system.

WYOMING ELIMINATOR AND TRAP

W. H. Nicholson Co., Wilkes Barre, Pa.

THIS ELIMINATOR COMBINES the steam separator and the trap for removing water from the receiving chamber. Separation of the steam from the water or oil is accomplished by means of a baffle plate, the moisture draining into the lower half or receiver which is the trap section. A valve is provided so that the connection to the trap can be closed in case it becomes necessary to take part of the apparatus apart for repair or cleaning.

The trap operates automatically to keep the water level at a certain height in its chamber by a float mechanism which governs the operation of this trap, controlling the main valve which permits of discharge of the water and is operated by the pressure of steam.



SECTION OF WYOMING ELIMINATOR

The pilot valve, operated by the float simply controls the opening or closing of the steam ports from the upper part of the trap to the valve piston, and this main valve piston controls the opening of the discharge valve.

As the float rises, the weight at the left hand side is thrown over, and when it reaches this point it comes with a quick motion, owing to the method of connection and lifts the float still further, thus, by means of a series of arms, opening the pilot valve. Steam then flows through the steam ports and behind the piston which pushes the discharge valve open.

As the float falls the pilot valve is closed, steam is shut off from the discharge valve piston, and the discharge valve is thrown closed by the pressure of the water.

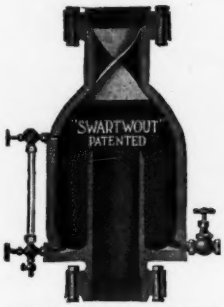
SWARTWOUT SEPARATOR

Ohio Blower Co., Cleveland, O.

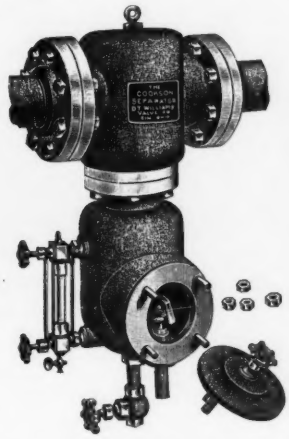
THE IMPORTANCE OF removing water from steam before it passes to the engine is too well known to engineers or those connected with power plants to need remark, as the loss of efficiency in an engine for every per cent moisture is well known to engineers. In developing Swartwout separators, a principle of "moral suasion" has been used rather than brute force.

The accompanying cut shows the vertical type of centrifugal separators as designed and manufactured by The Ohio Blower Co. A plate, twisted in the form of a helix, is inserted in the inlet of the separator. This plate is given a helical form as with this curve the particles of steam, oil and water rushing into the separator can be given a violently whirling motion without causing any interference with the flow of the steam.

Steam, oil and water enter the body of the separator, which has an area considerably larger than the pipe. The violent whirling caused by the swiftly moving steam sliding past the helical plate, results in the oil and water,



SWARTWOUT SEPARATOR SHOWING HELICO-CENTRIF·UGAL ACTION



COOKSON SEPARATOR, VERTICAL TYPE

which at atmospheric pressure are in the neighborhood of 1600 times as heavy as steam, flying to the outer walls of the separator, while the dry clean steam is caught by the straight outlet tube inserted well into the body of the separator as shown by the cut. This is extended in so that it will catch the steam before the oil or water has a chance to get mixed again with it.

As a combination of centrifugal force and a helical twisting motion is used here, it has been given the name of The Helico-Centrifugal principle of steam separation. It is absolutely positive in its action, a fixed mechanical law, and practically perfect results are claimed.

PITTSBURG SEPARATORS

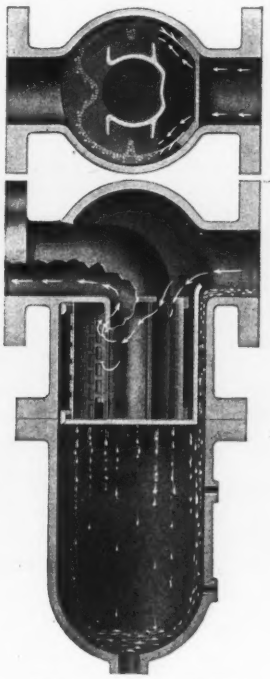
Pittsburg Gauge & Supply Co., Pittsburg, Pa.

THESE SEPARATORS ARE designed with the essential principle of whipping out of the steam by sudden change in direction of flow the water that has been entrained. The water is thrown out of the course of the steam or onto surfaces which will conduct it away, allowing no opportunity for its being picked up and carried on. In both the horizontal and vertical types, steam entering at full velocity is given a certain reversal of direction of flow with immediate reduction of velocity, using large areas, the sectional area of the body being at least 4 times that of the inlet and outlet connections. Regular and receiver forms are made in both the horizontal and the vertical type shown in the illustration, the construction being evident from the cut.

STRONG SEPARATORS

Strong, Carlisle & Hammond Co., Cleveland, Ohio

IN THE HORIZONTAL type which is the one illustrated, water flowing along the bottom of the pipe is caught by the projection of the cage and conveyed to the receiving chamber without entering the steam space of the separator. Entrained water which is carried in the current of steam goes around the inner pipe and is thrown out by centrifugal force against a perforated wall, passes through the openings and drops into the water space. The current of steam



STRONG HORIZONTAL STEAM SEPARATOR

SECTION OF THE PITTSBURG VERTICAL SEPARATOR

passing around the pipe is subjected to whip snapping action so that all moisture is thrown outward into the space between the wall and the separator proper and conveyed into the receiver space. The water drops to the bottom of the receiver and is entirely removed from the steam current so that the dry steam cannot take up moisture after it has once been separated. Vertical separators are also made embodying the same principle of action.

COOKSON SEPARATORS

The D. T. Williams Valve Co., Cincinnati, O.

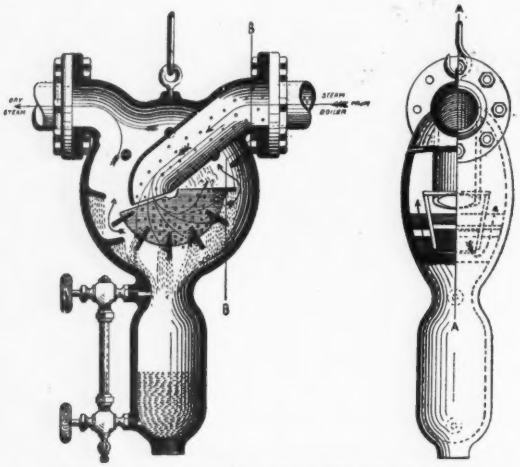
THESE ARE MADE in vertical and horizontal type, the vertical having a pyramid shaped baffle plate which covers the outlet and extends in the form of a cross in both directions. Steam, in order to pass this must go through the triangular ports in the corners of the cross and ribs on the top of the baffle plate catch the water which trickles down through port holes into a receiving space in the bottom of the separator.

In the horizontal type, a star shaped baffle in the center and wings cast on the walls of the separator give the steam a zigzag movement from inlet to outlet, each reversal of direction tending to take out moisture. The water passes through port holes at the bottom of the baffle into a separate chamber below, from which it is taken away by a trap.

WATSON & McDANIEL COMBINE SEPARATOR

Watson & McDaniel Co., Philadelphia, Pa.

THIS SEPARATOR SERVES as a reservoir for the engine, to prevent vibration of the steam pipe and also as a separator proper to insure delivery of dry steam. The path of the steam is clearly shown in the side section, also the action of the plates and of the whirling action in removing the moisture from the steam. Besides this, the reversal of current and



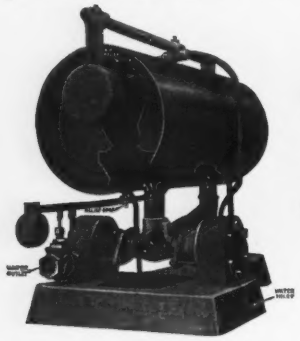
SECTION OF W. & M'D. COMBINE SEPARATOR

large volume in the separator, permitting of expansion of the steam and slowing down of velocity, are also utilized.

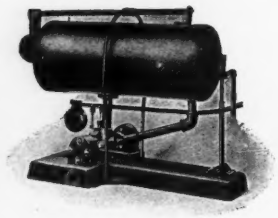
DETROIT STEAM TRAPS

American Blower Co., Detroit, Mich.

IN THE DETROIT nonreturn trap, condensation is delivered through the inlet into a cored chamber or port thence into a hollow trunion. This trunion has a partition which directs the flow up through a vertical



PARTIAL SECTION OF THE DETROIT SEPARATING TRAP



DETROIT NO. 10 STEAM TRAP, SIDE VIEW

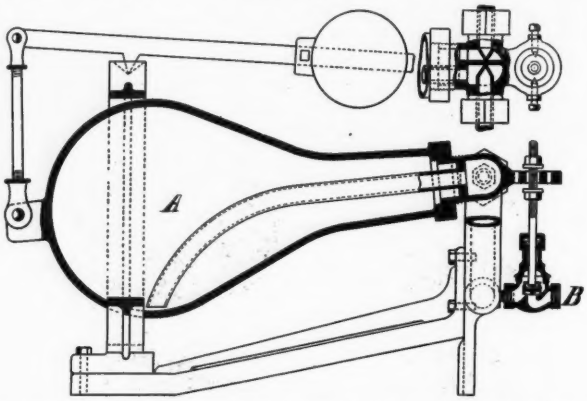
pipe into the trap tank, and this, as it becomes nearly filled, overcomes the weight of the counterbalance so that the tank tilts over, engaging a lever and automatically opening the discharge valve. The counterbalance is adjusted to bring the tank back into filling position before the entire contents are delivered, thus preserving a water seal.

To prevent air binding in the system, or in the tank, the relief air cock which is attached to a pipe extending through the inside of the tank and to a point above the highest water level, should be allowed to blow slightly all the time.

BUNDY SEPARATING TRAP

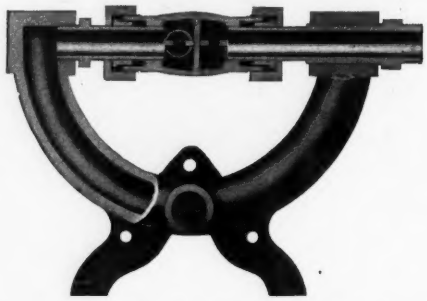
American Radiator Co., Bundy Dept., New York, N. Y.

THESE TRAPS ARE designed to separate water from steam and are used for draining separators, headers, steam pipes, etc., discharging directly to the atmos-



SECTION OF BUNDY SEPARATING TRAP IN POSITION FOR FILLING

phere or into hot wells, heaters or tanks. The Bundy separating trap uses the force of gravity as its motive power, giving it simplicity and reliability. In the filling position the trap stands with the tank at the top of the ring as indicated in the sectional view, and the valves are then so arranged that water will enter the bowl through one end of the trunnion. When the bowl has filled with water to a sufficient height so that the weight



ARRANGEMENT OF INLET AND DISCHARGE PASSAGES IN TRUNNION OF BUNDY TRAP

overcomes the ball on the lever arm, the ball drops and by the lever extension raises the discharge valve, permitting the steam pressure to force water from the bottom of the bowl up through the curved pipe to the trunnion,whence it flows out of the end opposite that at which it entered and down through a channel in the curved support to the discharge valve, which is labeled B in the sectional drawing. When the water is discharged down to 2 in. from the end of the curved pipe the bowl rises and closes the discharge valve.

ANDERSON MODEL D STEAM TRAP

V. D. Anderson Co., Cleveland, O.

IN THIS TRAP the float is reinforced by copper bands and works directly on the outlet valve. Condensation enters through the inlet and strainer, and falling to the bottom of the trap forms a water seal of 3 to 4 in. and then lifts the float, which rising draws the valve open just sufficient to allow water to escape as fast as it enters. The nozzle at the end is of sufficient diameter to admit the float so that the whole mechanism can be taken out for examination.

By means of the bypass, which is operated by the handle attached to the cover, the valve may be lifted free of the seat if it is desired to let the water blow through by force of the steam. At the top of the trap is an air cock to be opened when steam is first turned on and closed as soon as steam appears. This is used because the accumulation of air in the trap will prevent condensation from entering and, if at any time the trap does not drain properly, it is usually because of air binding, which can be relieved by opening the air cock.

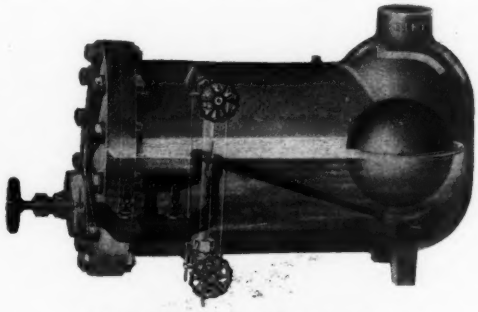
Under proper working conditions the water will stand at a height of about 3 in. in the gage glass, thus keeping a water seal always on the valve.

All parts are interchangeable and valve and valve seat may be changed for different pressures, by taking off the lid to the nozzle, unscrewing the valve seat lock nut and lifting it and the seat out, then pulling the valve out of the holder which is split and springs onto the valve stem.

THE DAVIS IMPROVED STEAM TRAP

The G. M. Davis Regulator Co., Chicago, Ill.

IN THIS TRAP, inlet is from the top and water accumulates in the body of the trap until it lifts the float which rises, opening cone shaped balanced valves and permitting the water to be discharged. The trap



DAVIS IMPROVED STEAM TRAP

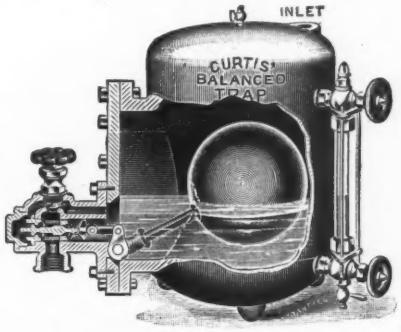
discharges continuously as fast as water enters, and will only close when the float has dropped to the point for which the valves are set. The closing always occurs however while the valves are still effectively sealed by several inches of water, thus preventing any leakage of steam. Two valves are provided, thus giving large discharge capacity and as they are balanced they do not hinder the action of the float. All working parts of the trap are carried on the head and may be removed without breaking either inlet or outlet connection.

CURTIS BALANCED STEAM TRAP

Julian d'Este Co., Boston, Mass.

THIS CONSISTS OF a heavy cast-iron vessel with rounded ends having on one side a nozzle of sufficient diameter to admit the float, this float and the valve being carried on the flange which covers the nozzle. The valve proper is attached to the flange by tap bolts and may be removed without taking off the cover, the float stem permitting it to be pulled out far enough so that the knuckle can be unscrewed from the float stem.

The valve consists of 2 disks of equal area on a single stem, one with a short sliding fit, the other with ground seat taper fit which guides it to its seat, and the valve stem is guided by 3 arm spider loosely connected by a



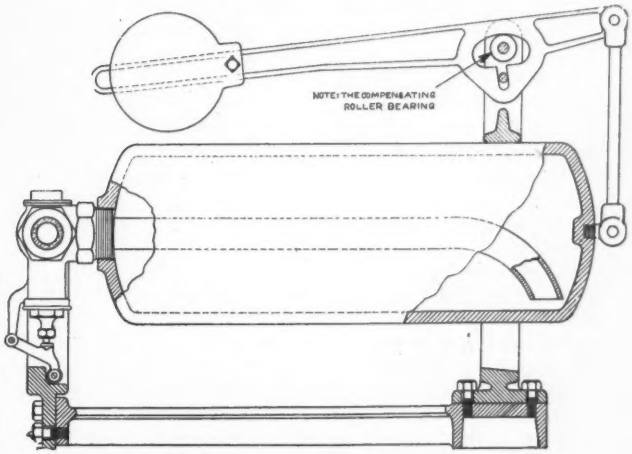
SECTION OF CURTIS BALANCED TRAP

knuckle joint and stem to the float. From the sectional view of the trap it is evident that as the float falls the valve will be pulled closed, while as the float rises the valve will be shoved open, permitting the water to escape. As the outlet valve is near the bottom of the water chamber and the inlet is on the top, the trap will work against any back pressure less than the direct pressure inside the trap.

GOLDEN TILTING STEAM TRAP

Golden-Anderson Valve Spec. Co., Pittsburg, Pa.

AS SHOWN IN THE sectional view, this trap consists of a tilting body having inside a discharge tube and balanced by a counter-weight and lever. Condensation entering into the hollow trunion passes into the receiver and the weight of this condensation overcomes the coun-



GOLDEN TILTING STEAM TRAP IN SECTION, SHOWN IN FILLING POSITION

terweight causing the trap body to fall. This motion opens the auxiliary valve, allowing pressure to act on the piston and this in turn opens the main valve allowing the water in the receiver to discharge through the curved pipe and an outlet in the trunion.

When the water has emptied to the desired level the balance weight lifts the trap body to filling position; this

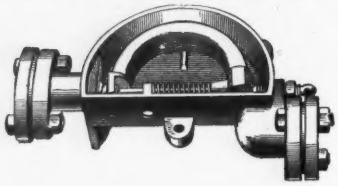
releases the auxiliary valve, allowing the main valve to close without shock or jar. The compensating roller bearing on which the lever works eliminates all shock when the trap tilts. The valves for this trap are made and tested for pressures up to 275 lb., and have large area to handle a large volume of condensation. Operation of the trap is positive at all times and the discharge is prompt, speedy and practically noiseless. The auxiliary and main valves are carried on the middle of the trunion as seen in the illustration.

THE MARCK STEAM TRAP

E. F. Houghton & Co., Philadelphia, Pa.

IN THE MARCK trap the essential feature is the tube spring which is made of selected metal, is hollow and bent crescent shaped. This tube placed in a metallic case constitutes the trap, the tube being filled with a liquid and hermetically sealed so that there is no possibility of leakage. This liquid is of such a nature that it becomes a gas at 212 deg. F. and exerts a pressure on the tube, tending to straighten it out.

The valve is carried on the end of the spring tube, and when no steam is on the trap, the temperature being below 212 deg., the spring is contracted and the valve



INTERIOR OF THE MARCK TRAP

THE MARCK OPERATING MECHANISM

wide open. When steam is turned on, the trap remains open for a few moments until the tube spring becomes heated, evaporating the liquid and closing the trap. During this time of opening, all water, scale or dirt is blown out of the trap.

After the trap has closed, the accumulation of water in the coil cools the tube spring and it contracts gradually, allowing the valve to open and drain out all water that may have accumulated in the pipe, or to close immediately, if the slightest amount of live steam attempts to pass. The tube action is extremely sensitive, so much so that the trap will open to discharge less than half an ounce of water but will close quickly enough so that a lighted match can be held in front of the trap outlet and will not be extinguished. The Marcy steam trap becomes therefore an automatic valve for carrying off water that may accumulate at any point.

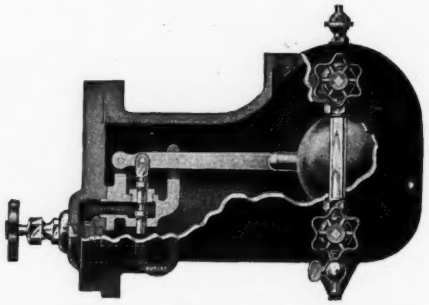
By removing the cover to the casing and taking out one screw, the tube spring which is the entire working mechanism may be removed. Each trap is tested to work under any pressure from 0 to 200 lb., but the operation of the trap is quicker and more effective at pressures of 80 lb., and less, so that for draining systems where the pressure is very high, the use of a reducing valve in the line leading to the trap is advised by the manufacturers.

ECLIPSE STEAM TRAP

Hughson Steam Specialty Co., Chicago

THE INTERIOR VIEW of this trap shows the float and its connection with the double-ported valve. This valve is so constructed that it is perfectly balanced and may be used, therefore, for high or low pressure. When the trap has filled from the inlet in the top to a point where the float is carried upward, it opens the valve slightly and permits water to drain away as rapidly as it enters the trap. It is thus of the continuous operation type.

All working parts are bolted to the cover and can be removed without disconnecting either inlet or out-



INTERIOR VIEW OF ECLIPSE STEAM TRAP

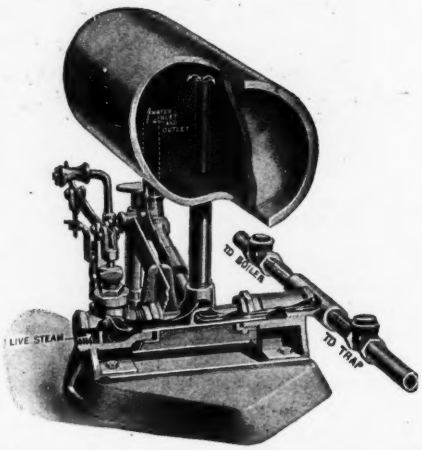
let pipe, and a by-pass is provided for blowing out and cleaning off any scale or sediment. A seal of 2 in. of water always remains in the trap to seal the valve.

MOREHEAD TILTING STEAM TRAP

Morehead Mfg. Co., Detroit, Mich.

THIS TRAP CONSISTS of a steel tank, the head and longitudinal seams of which are closely riveted and brazed, swung on a brass trunion between 2 supports secured to a cast-iron bed. The supports consist of the valve connection on the one side and the water connection on the other side, both of brass and forming a secure and suitable rest for the trunion.

Admission and discharge of condensation take place at the water end of the trunion while the valve end serves as an admission port for live steam. This valve serves as a steam admission port for the return trap and has a removable disc, which provides, at the proper time, a discharge for the contents of the trap. The tank is counterbalanced by a cast-iron counterpoise weight on the end



SECTION OF MOREHEAD TRAP IN FILLING POSITION

of a wrought-iron lever. At the point of application of this lever to the tank, an extension rod engages with a lever controlling the steam valve.

Leading from the valve casting of the trap is a weighted automatic relief valve, operated by a link connection from the steam valve lever. Bolted to the bed plate, in a position just under the ends of the tank, are

2 upright buffers which serve to limit the swing of and provide resting points for the trap in its filling and discharge positions.

The trap tank is maintained normally in a horizontal position by means of a weighted lever. When sufficient water has entered the trap to overcome the action of the lever, the tank tilts downward, automatically opening the live steam valve, admitting steam at full boiler pressure above the condensation in the tank. The resulting equalization of pressures in the trap tank and boiler permits the natural flow of water from the trap to the boiler, if the tank is above water level.

The valve provided for relieving the trap tank of all air pressure during the period of filling, is automatic in its operation and positive in action under all conditions. Movement of the levers operating the valves is so graduated that it is impossible for the valves to pound themselves to pieces, or to permit the trap becoming air-bound.

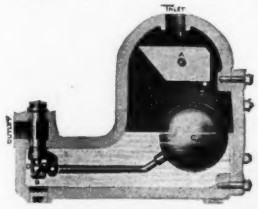
Adjustment of the weight on the main lever is such that, while allowing for the normal discharge of the contents of the tank, it prevents the discharge of that amount necessary for an effective water seal.

THE NASON-VESUVIUS TRAP

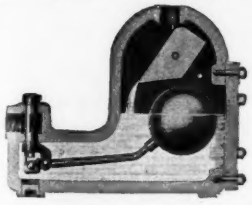
Nason Manufacturing Co., New York, N. Y.

THE NASON MANUFACTURING CO. of New York has manufactured steam traps for the past 70 years, being the originators of the Nason trap and the Nason-Vesuvius which is a later type, placed on the market after a long tryout period.

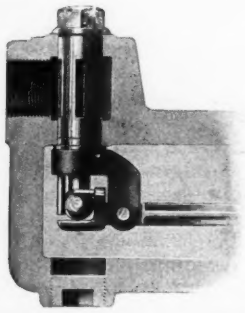
Figure 1 shows the Nason-Vesuvius trap in its receiving position, while Figure 2 shows it relieving the system of a charge of water. Operation of the trap is as follows: Water enters the trap at the inlet, Figure 1, and is received in the tilting copper bucket, A. This bucket when empty is maintained in a horizontal position as shown, but when full of water it becomes unbalanced and dumps its charge of water into the body of the trap, Figure 2. The quick upward impulse imparted to the



NASON-VESUVIUS TRAP RECEIVING WATER



NASON-VESUVIUS TRAP IN DISCHARGING POSITION



DETAIL OF NASON-VESUVIUS VALVE

float C by this discharge instantly removes the ball from its seat, and this instantaneous action of the ball allows a clear free-way for the discharge.

In closing, the float follows the receding water level and gradually returns the ball toward its seat until a predetermined level is reached. At this point the pressure picks up the ball and instantly seats it, thus closing the discharge orifice, until the above described operation is repeated.

As will be observed from the large detail of the valve, the ball is held in position by cage D, Figure 1. The stationary and movable pins comprising this cage are so arranged that a positive rotating motion is imparted to the ball with each discharge, thus offering a different surface of the ball at each seating.

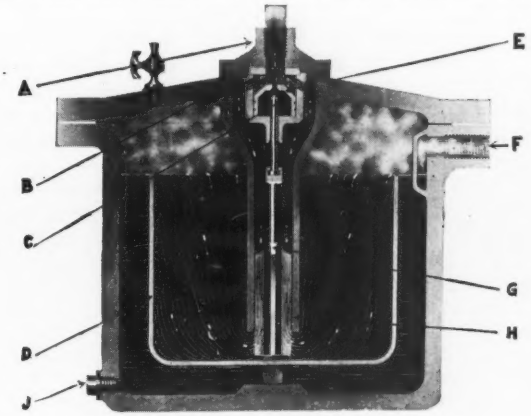
It will also be observed that if at any time it is necessary to repair the trap, a new ball and seat can be put in in a few minutes' time and at a very small cost.

THE VANCE STEAM TRAP

Geo. M. Newhall Engineering Co., Philadelphia, Pa.

BY REFERRING TO the sectional view of the trap it will be noted that there are 2 openings for the discharge, the auxiliary valve opening, and the opening of the main valve which is at least 5 times as large in diameter as is the auxiliary valve opening, so that the Vance trap will discharge quickly a great quantity of water.

The method of operation of the trap is as follows: The flow of condensation enters the trap on the right, is thrown against the baffle plate and distributed evenly around the inner walls of the trap. As this space fills with water the bucket floats and closes the valve;



SECTION OF THE VANCE TRAP.

then the water in the trap gradually rises to the top of the bucket and starts to flow into the bucket. When the water in the bucket has reached a certain height, the bucket starts to drop, and the overflow immediately filling the bucket, gives it power to pull the valve from its seat.

The auxiliary valve is attached to the winged guide by a slip joint, which, it will be noted, has enough play to allow the bucket to be fully started on its way downward before there is the slightest pull on the valve, so that its action is positive and instantaneous. The moment the auxiliary valve removes the pressure from under the main valve the latter starts to drop of its own weight, accelerated, as soon as it moves from its seat, by the pressure of the water on its upper surface, consequently the trap acts with great precision both in opening and closing.

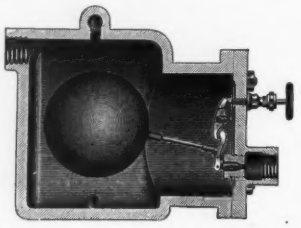
The winged guide is 1/16 in. less in diameter than the discharge tube to avoid sticking and guide the auxiliary valve to its seat.

Valves at the top of the trap are out of harm's way and the discharge tube is always water sealed. This discharge tube is part of the main lid of the trap so that, if the lid is in place, it is in proper position. The bucket rests on a boss in the bottom of the trap, to keep it from coming in contact with any mud or scale that might collect at this point.

RELIANCE STEAM TRAPS

Reliance Gauge Column Co., Cleveland, O.

WATER ENTERS AT THE inlet at the left-hand side, filling the trap until the upward pressure on the float raises it and thus opens the valve. If there is slight inflow of water the valve opens slightly and in case of a large inflow the float rises higher and the



SECTIONAL VIEW OF RELIANCE STEAM TRAP.

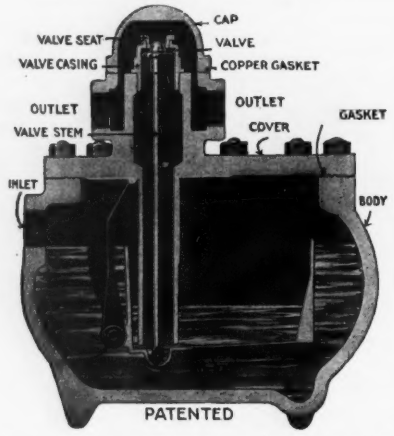
valve opens wider. A hand-wheel situated above the outlet serves to force the valve open if desired, permitting the trap to be blown out with steam. All mechanism is attached to the cap and can be taken out by removing this cap from the end of the trap.

SQUIRES IMPROVED STEAM TRAP

The C. E. Squires Co., Cleveland, O.

IN THIS TRAP all joints are above the water line and exposed to steam only so that there is no contraction and expansion due to immersion first in water and then in steam, and there is no corroding action from the water. The cast iron bucket is hinged on bearings which are tapered to an open end so that there is no chance for accumulation of solids to affect its operation. Surplus weight of the bucket is all added at the outer end to give great pulling force in opening the valve.

By removing the cover, the entire working mechanism comes out of the trap and any part can be inspected or changed in a few minutes. Inlet is at the left hand side of the trap and outlet through the tube and the valve at the top. The pipe connections to the outlet can be made



SECTIONAL VIEW OF SQUIRES IMPROVED STEAM TRAP

on either side, leaving the other side plugged. The valve is made with a spherical surface at the seat to insure a tight seat.

Discharge is intermittent through a wide opened valve, an effect which assists in drawing the water to the trap, from pipes, separators or coils. Valves and seats are of bronze metal, with figures cast on them to signify the highest pressure under which the trap will operate. Water entering the trap from the inlet falls to the bottom and lifts the bucket thus closing the valve, until the water level has risen to the point where water overflows into the bucket when the valve is pulled open and the steam pressure forces the water up through the tube and out of the valve, until the condensation in the trap body having reached the low water line the empty bucket again rises from the lifting power of the water. The valve is closed when the water level is sufficient to seal the bottom of the discharge tube.

For very large discharge a special valve mechanism is installed which opens very rapidly. This mechanism can be installed on any size trap made by the C. E. Squires Co., by simply changing the cap which contains the valve mechanism for one of greater vertical dimensions.

THE STRONG STEAM TRAP

Strong, Carlisle & Hammond Co., Cleveland, O.

THE STRONG STEAM TRAP is of the bucket type, having an open cast-iron bucket which is direct connected to the valve by a single rod. The bucket is hinged by means of a Tobin Bronze Tube, and is connected at a leverage of better than 6 to 1, so that it exerts a great pulling force in opening the valve which is placed above the bucket and at the top of the trap. Operation of the trap is as follows:

Water of condensation enters the trap at the inlet and floats the bucket. As soon as the body of the trap fills with water, the water flows into the bucket, and causes it to sink. This opens the valve and a volume of water equal to that in the bucket with the exception of a small portion remaining in the bottom of the bucket, and the difference in the trap body represented by the difference between the rise and fall of the bucket. The internal pressure forces the water out through the valve and into the atmosphere or a receiving receptacle.

Buoyancy of the bucket is such that a small amount of water always remains in the bottom of the bucket, and covers the bottom of the discharge tube. This causes a water seal, which makes it impossible for the steam to escape. Each trap is subjected to a hydraulic test of 600 lb., and also steam pressure in accordance with the valve in the trap. By means of interchangeable valves the same trap may be used for any pressure from 0 to 250 lb.

By removing the cap on top of the trap, the valve and seat are open to inspection, and as the valve body and seat are attached to the cap, the wearing surfaces are brought to full view. The valve is of the ball type and forms a perfect joint as soon as the valve touches the seat.

The trap has 2 outlets—the lower or side outlet for draining the trap, and the upper outlet for testing purposes. By placing a valve in the upper outlet the trap can be tested while in operation, by opening the valve so that the discharge is into the atmosphere. As the trap is intermittent, if the valve closes tight. the discharge is instantly stopped and a glance tells whether the valve is perfectly seated.

WALWORTH STEAM TRAP

Walworth Mfg. Co., Boston, Mass.

THIS TRAP HAS an outer shell or receiver, and an inner open float into the bottom of which a brass cylinder is screwed. The tubes move up and down slightly with the float on a brass spindle, and the end of this hollow spindle is tapered to form a seat or valve which

is closed when the float is lifted up by the buoyancy of the water in the outer shell.

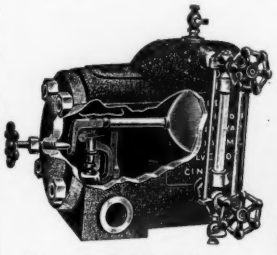
As condensation accumulates, it flows over and fills the float which drops away from the open end of the brass spindle and water is then forced up by steam pressure, through the spindle and out through the cover of the trap, until the float becomes light enough so that the water outside again forces it upward, closing the valve. Inlet is at the left hand side, and outlet from the right hand side, and at the bottom of the outer casing is a blowoff cock for removing any sediment which may accumulate. The bypass is used simply for blowing out the trap.

THE McDANIEL STEAM TRAPS

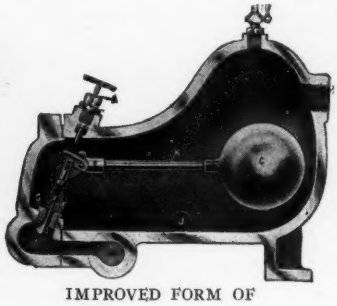
Watson & McDaniel Co., Philadelphia

THE EARLIER FORM is of the continuous type with the float acting directly on the valve spindle. The valve is of the plug form of phosphor bronze so that it does not stick, and the copper floats are seamless, therefore, do not collapse. The counterbalance weight on the end of the float lever gives the float extra lifting power, and permits of a large valve area. As the float always drops to the point where the valve will close before water is entirely drained from the trap body, the water seal is always maintained on top of the valve. Connections are such that by removing the cover of the trap the entire working parts are accessible, and at one end of the cover is a valve which when screwed down engages the counterweight, forcing the float up and opening the valve.

In the McDaniel Improved steam trap, the same direct acting principle is used, but a balanced valve has been employed thus eliminating the counterweight. This permits also the use of a heavier float which will therefore stand very high pressure without injury. The valve seat is placed above the bottom of the trap so that sediment will not enter it,



THE COOKSON HIGH PRESSURE FLOAT TRAP



IMPROVED FORM OF M'DANIEL TRAP

and the working parts are all connected to the bonnet at one end of the trap so that by removing this bonnet all parts are removed for inspection or repair.

THE COOKSON HIGH PRESSURE TRAP

D. T. Williams Valve Co., Cincinnati, O.

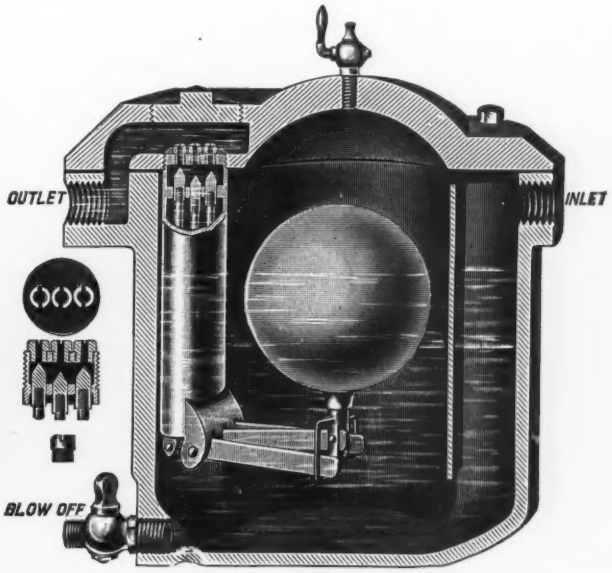
THIS TRAP IS designed for steam pressures from 100 to 200 lb., and particular attention has been paid to simplicity and accessibility. Condensation enters at the top of the trap and falls to the bottom, first forming a water seal to prevent steam from escaping. As water rises, the float is lifted, in turn opening the valve, allowing the water to discharge through the outlet at the bottom as fast as it enters. It is of the continuous flow type and is, therefore, always in operation, ready to respond instantly to large amounts of water entering. One end of the trap is removed by the use of a wrench, taking with it all working parts for inspection and repairs without in any way disturbing piping connections. By means of the bypass operated by the handwheel in the cover, steam can be blown through at any time to clean the seat and the surface of the valve.

WRIGHT EMERGENCY HIGH PRESSURE STEAM TRAP

Wright Mfg. Co., Detroit, Mich.

THESE TRAPS IN regular patterns are intended for pressures up to 200 lb. and in the special emergency pattern will operate under pressures up to 300 lb. At the top of the trap are 3 valves located at the highest point, and entirely removed from accumulations of grit or sediment. Condensation enters the trap at the inlet on the right, filling it to about the center, thus forming a seal of 4 to 6 in. of water at both inlet and outlet, as the inlet is separated from the body of the trap by the partition shown. There is, therefore, no possibility of escape and waste of steam.

When filled to this point the float rises, opening the center valve. If but little water is coming in, this one valve will take care of the flow, but if water comes in at a faster rate than the one valve can discharge, the float will rise still further, opening the right-hand valve



SECTIONAL VIEW OF WRIGHT EMERGENCY TRAP AND DETAIL OF VALVES

sufficiently to discharge the surplus or wide open, if necessary. If the capacity of these 2 valves is not sufficient, the further rise of the float opens the left-hand valve, giving a discharge equal to the full capacity of the inlet pipe. Ordinarily one valve is able to do the work, leaving the other 2 in reserve for emergencies.

It will be seen by inspection that removal of the cover brings all working parts accessible for inspection and repairs, without disturbing either inlet or outlet connection. Blowoff at the bottom removes all accumulation of sediment whenever necessary. Valves are conical and pass through a bar near the top of the outlet tube, to guide them accurately to the seats. Both valves and seats are renewable without removing the cover of the trap by taking out the iron plug above the

outlet tube. Floats are seamless copper, reinforced at the essential point of attachment to the valve levers by an extra thickness of metal.

BEST VALVES

Best Mfg. Co., Pittsburg, Pa.

THE BEST GLOBE valve is made principally with solid bronze disk with guide wings cast thereon which insures the disk seating properly. The seat is integral with the body of the valve but a bronze seat ring screwed in can be furnished if desired. With guide wings on the disk, the design is such that change of temperature does not warp the seat, consequently there is no bind in opening or closing the valve. With the seat integral with the body in the globe type of valve, there is no possibility of expansion and contraction loosening the seat and causing a leak.

A feature of the larger valves is a bypass inside the valve. In the center of the disk is a small opening against which the bottom of the stem bears. This opening acts as the bypass and is not closed until after the valve disk has seated and the stem makes another turn, bringing the end of the stem against the seat in the bypass opening.

The Best adjustable wedge gate valve permits of the disks adjusting themselves to any inequalities caused by wear on the seat rings. These wedges are in 2 parts made male and female, or, in other words, one half of the disk has a convex bearing on the back and the other half has a concave bearing on the back, these bearings being directly in line with the seating. On the sides of the disks are cast lugs which engage in guides cast in

PHANTOM CUT OF BEST GATE VALVE WITH EXPANSION WEDGE

the inside of the body, preventing the disks coming in contact with the seats until they are at the point of closing; this avoids wear and any dragging of the disks on the seat rings.

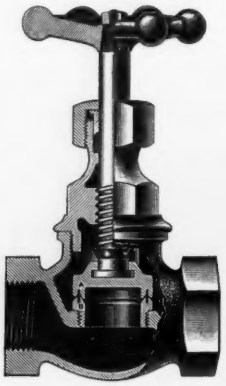
With this construction the outside screw and yoke valve can be made of one-piece bronze or steel stem, thereby obviating any possibility of the disks dropping off the stem. Stems are also furnished in 2 pieces, a malleable-iron or cast-steel disk holder, into which the bronze or steel stem is screwed and carefully pinned, a construction less expensive than the one-piece bronze stem. The seat rings are screwed into the body to a shoulder which relieves all strain upon the threads and provides against the unequal expansion of the bronze and iron.

Valves for superheated steam purposes are provided with nickel steel or nickel bronze seat rings, disk facings, stems, or other parts that are affected by the high temperatures.

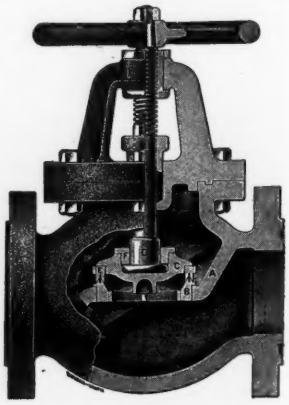
CROSBY SPRING SEAT VALVES

The Crosby Steam Gauge & Valve Co., Boston, Mass.

IN THESE VALVES which are made with gun metal body from ¼ up to 3 in., and with iron body from 2½ to 12 in., both disk and seat are made with a slotted V-shaped spring surface, so that as they come together a spring action tends to give a tight joint. Because of the groove in the edge of the seat any slight grit that may lodge there will drop into this groove, and



CROSBY SPRING SEAT VALVE, SMALLER SIZES



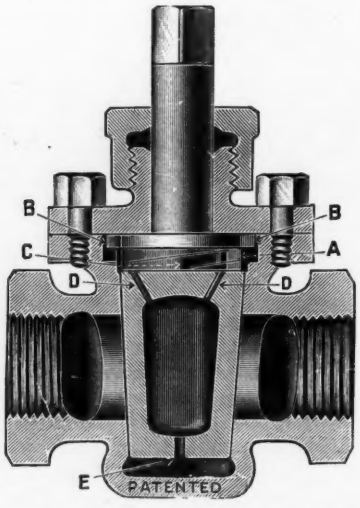
IRON BODY SPRING SEAT VALVE

the sweeping action of the steam will throw it out and carry it away. These valves are tested under hydraulic pressure of more than 400 lb. to the sq. in. before shipment.

HOMESTEAD VALVES

The Homestead Valve Mfg. Co., Pittsburg, Pa.

THIS VALVE IS of the plug cock style, but is especially adapted for high pressure work and has the advantage that when the valve is open the seat and face of the valve are protected from the action of the steam. Also it gives a straight passage through the valve. Like other plug valves, it opens or closes full with a quarter turn of the handle, but as shown



SECTION OF HOMESTEAD PLUG GATE VALVE

by the sectional view of the straightway and the 4-way external view, the plug is entirely enclosed in the valve body and has a packing gland around the stem.

This plug is held to its seat by a patent floating cam which is like a washer with 2 inclines cast on the bottom surface, and a lug extending from each side,

the top of the cam being flat and fitting against the bottom of the valve bonnet. On the top of the plug are also 2 inclines in opposite direction to those on the cam so that after the plug has turned ¼ way in the direction of closing, it is prevented from turning further by the lugs at the side which fit into the grooves in the body of the valve. The cam then rises on the inclines and, when it can rise no further because of coming in contact with the top of the valve, the inclines press down on the plug and force it to

THE HOMESTEAD 4-WAY VALVE

a firm seat. In opening the valve, a slight jar of the handle breaks contact between the plug and the cam surfaces and the plug then rises slightly and is opened with ease.

JENKINS VALVES

Jenkins Bros., New York, N. Y.

JENKINS BROS. renewable disc valve has brought before steam users a radical departure from the solid metal seat pattern.

The standard pattern, brass, instead of employing a solid metal clapper, are fitted with the Jenkins composition disc, contained in a brass disc-holder, and this disc when the valve is closed rests upon a raised brass seat in the body of the valve. The Jenkins disc being somewhat softer, presents a slightly yielding surface to the raised valve seat, and adapts itself to any roughness or unevenness of the seat, thereby insuring perfect tightness.

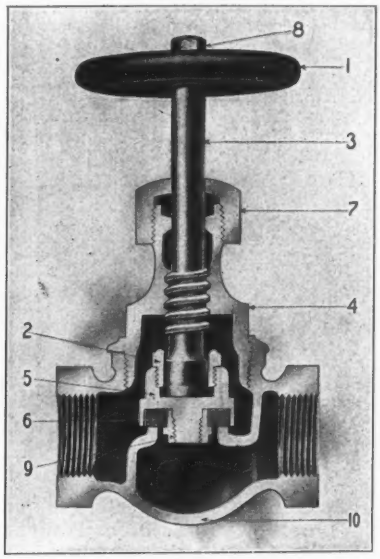
In the case of grit or scale lodging on the seat, this foreign matter usually imbeds itself in the composition disc without injury to the metal seat. If the disc

JENKINS' DISC, NUT AND PACKING RECESS.

should become cut on account of valve being throttled constantly, or become worn out through hard service, a new disc can be substituted quickly and cheaply.

While the composition disc was the principal feature of the original Jenkins Bros. Valve, from time to time improvements have been made to keep these valves up to the high standard established many years ago. The disc removing nut and nut-lock was designed to facilitate the removal of the Jenkins disc from the disc-holder; the flattened hole corresponding in shape to the projection on the disc-nut, and the assembled disc and nut are shown in the illustrations. If the disc and nut are assembled as shown and screwed into the holder, it will be impossible for the nut to unscrew without the disc turning, as the disc and nut are locked.

The keyed stuffing box consists of a deep, hexagonal recess cast in the top of the valve bonnet to hold the packing, which, when compressed by the waste nut is forced into this recess so that both nut and packing are prevented from turning with the spindle.



JENKINS' BRASS GLOBE VALVE, STANDARD PATTERN.

Another important feature of these valves is that they can be packed under full pressure, as when the valve is wide open the rounded surface of the lock nut sets tightly against the under side of the bonnet, making a steam-tight joint and permitting the waste nut and packing to be easily removed and replaced.

All Jenkins Bros. brass valves, standard pattern, are designed and guaranteed for a working pressure of 150 lb., and are adapted for use in steam, hot or cold water, oil, air or gases.

As regularly furnished, all the valves are fitted with Jenkins discs of hard composition, which soften slightly under the action of steam or hot water. For cold water, air or gases, a slightly softer disc is supplied.

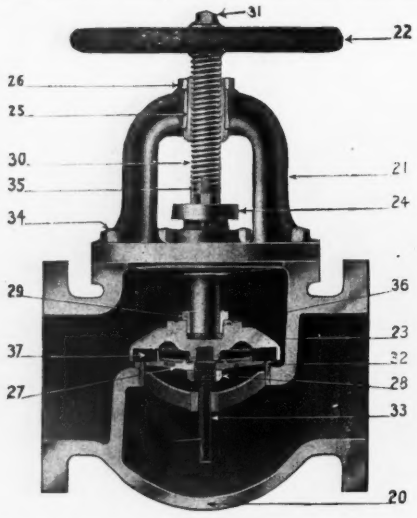
All parts are standardized and perfectly interchangeable. Repairs on any Jenkins Bros. valve can be easily and quickly made, as any number of Jenkins Bros. valves of a given size and pattern can be taken apart and the parts mixed up and reassembled with perfect results.

Jenkins Bros. iron body globe, angle and cross valves, standard pattern, are heavy and strong and are regularly fitted with Jenkins renewable composition discs; the working parts are similar in construction to the Standard pattern brass valves. The raised seat rings in these valves are made of high grade steam metal screwed into the body of the valve, and if necessary can be removed and renewed, thus after long wear making the valves as good as new at nominal expense, without necessitating their removal from piping.

Jenkins Bros. also manufacture a full line of extra heavy valves which are designed for 250 lb. working pressure on the same general design as the Standard pattern. As regularly made all these extra heavy

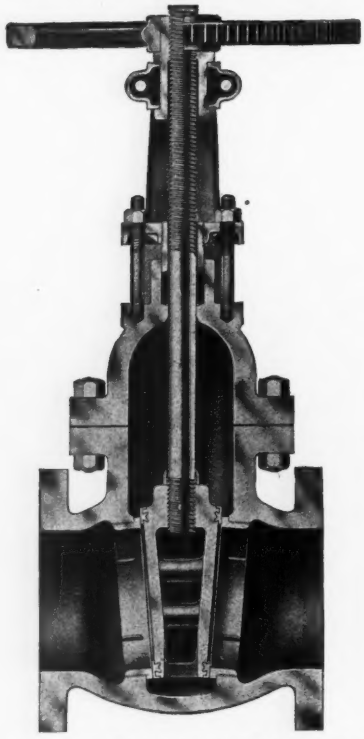
valves are tested to 800 lb. hydraulic pressure. The factor of safety is so high, however, that the test pressure can be increased to double this figure if required and the valves may be safely used on hydraulic or air pressures up to 800 lb.

Jenkins Bros. Automatic Equalizing Stop and Check Valves are designed to shut off, automatically,



SECTION OF JENKINS IRON BODY VALVE, COMPOSITION MOUNTED

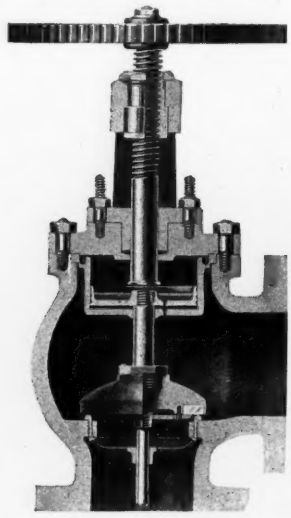
the flow of steam from the header to a boiler in case a tube should burst or other internal rupture occur, thereby suddenly reducing the pressure in the boiler.



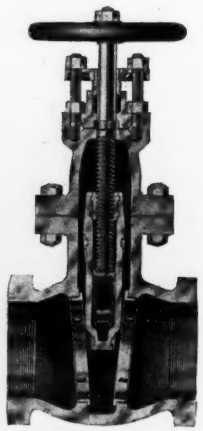
EXTRA HEAVY GATE VALVE WITH OUTSIDE SCREW

They also serve to equalize the pressure in a battery of boilers and prevent one boiler from working at a lower pressure than the others. As the valves can only be opened by the pressure in the boiler, it is impossible accidentally to turn steam into a boiler which is being cleaned. To prevent chattering, the valve is cushioned by an internal dashpot made of bronze which eliminates all danger of sticking through corrosion.

In the design, strength and rigidity have been carefully considered and they will easily withstand the



JENKINS AUTOMATIC STOP AND CHECK VALVE



SECTION OF IRON BODY JENKINS GATE VALVE

stresses caused by expansion and contraction of the piping and the steam pressure. Each valve is carefully tested to 800 lb. hydraulic pressure and is guaraneed for working steam pressures up to 250 lb. The stuffing boxes can be packed when valve is wide open under full pressure. Ordinarily spindles, seat rings, etc., are of bronze and bodies and bonnets of cast iron, but if desired, the bodies and bonnets are made of semi-steel.

For high pressure superheated steam, valves are made from these patterns with bodies and bonnets of cast steel, having a tensile strength of 68,000 to 70,000 lb. The seat rings, discs, spindles and dashpots are made of Monel metal which in addition to being very hard and noncorrosive has the same coefficient of expansion as the cast steel, thus providing a combination which experience has proved to be best adapted to withstand the destructive effects of the sudden and frequent wide variations in temperature which usually accompany the use of superheated steam. All connecting flanges are made with raised faces inside bolt holes, and approved high pressure gaskets or ground joints as may be specified. Bolt holes are counterfaced for nuts.

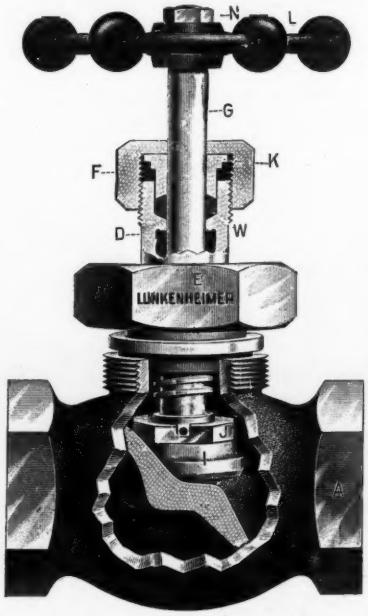
Jenkins Bros. gate valves are made in brass and are guaranteed for steam pressures up to 150 lb. The smaller sizes have solid bronze wedges with double face, while the wedges in the larger sizes are of cast iron faced with hard bronze rings. The wedges or gates have grooves which slide smoothly on ribs cast in the inside of the valve body, and this prevents uneven wear of the faces of the wedge, or chattering when the valve is partly open.

The bodies are globe shaped which secures valves of the greatest possible strength, besides good proportions and neat appearance.

Both brass and iron body valves are made either with inside screw, stationary spindle or with outside

screw and yoke, rising spindle. Iron body valves are furnished with or without bypasses, as ordered.

Jenkins Bros. also manufacture a full line of extra heavy gate valves, brass and iron body, inside screw and outside screw and yoke patterns. The general design of these valves is similar to the medium pressure gates but they are much heavier and stronger throughout. The valves are designed for 250 lb. work-



SECTION OF LUNKENHEIMER REGRINDING VALVE

ing steam pressure, have an ample factor of safety, and are tested to 800 lb. hydraulic pressure.

The iron body valves can be furnished with bypass and their use is recommended on sizes 8 in. and above. The bypass is made inside or outside screw to match the main valve. Bypass bodies and elbows are combined in a single casting of special design secured to main valve by a single flange making a strong, compact arrangement and reducing the number of joints required. Valves, both main and bypass can be furnished with spur or bevel gearing, extension spindles, or floor stands to suit requirements.

For superheated steam are made with bodies, bonnets, discholders, and wedges of cast steel. The seat rings, discs, and spindles are made of Monel metal, a natural alloy containing about 7 per cent of nickel, hard, durable, noncorrosive, and having practically the same coefficient of expansion as cast steel.

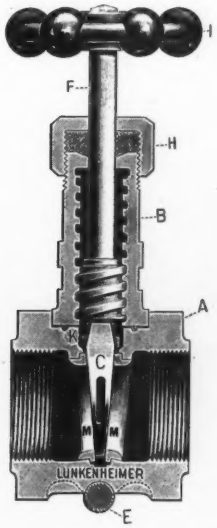
The connecting flanges have raised faces and approved joint packings or ground joints as may be specified. They are suitable for working steam pressures up to 350 lb. and total temperature of 800 deg. F.

LUNKENHEIMER VALVES

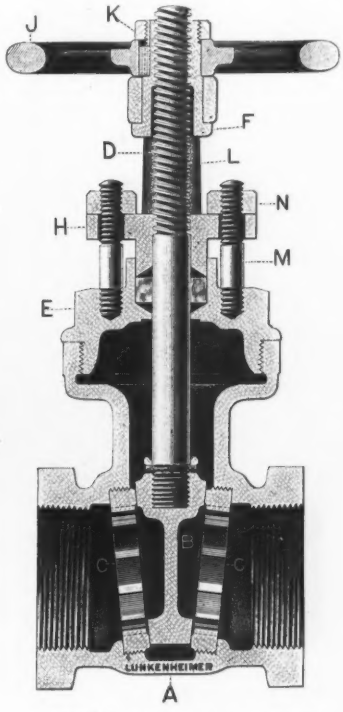
The Lunkenheimer Co., Cincinnati, O.

IN THESE VALVES, which are of various types, the effort has been made to secure a valve which will not need disconnection from the pipe under any conditions. In the regrinding valve, the disk is carried on the lower end of the stem and is so arranged that by removing the ring which holds the hub to the body, the screw which forces the valve downward may be allowed to turn freely. A little powdered sand or glass and soap or oil are then put on the disk of the valve, a wire pin is inserted through the valve stem and a slot in the upper surface of the disk, thus locking the disk and stem together and the disk is rotated on the seat, the stem rotating in the bonnet which serves as a guide.

Steel seat reamers are furnished in case the seat should be badly cut, but their use is rarely necessary.



CLIP DOUBLE SEATED GATE VALVE



VICTOR GATE VALVE WITH RENEWABLE WEDGE AND DISK

The stem is made with a shoulder on it, which seats against the bottom of the stuffing box, thus permitting of repacking the stem while it is under pressure.

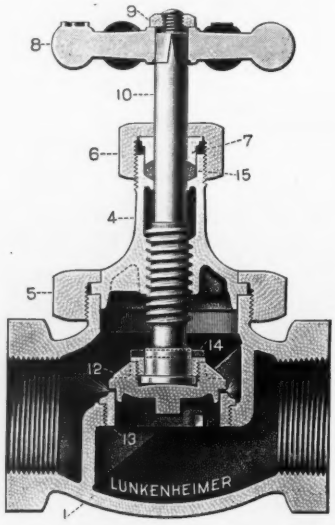
In ordinary use the hub which carries the nut for the thread on the valve stem is held to the body of the valve by a union ring which screws around the outside of the neck of the valve. Another type has a yoke and outside stem but works on the same principle. The ends of Lunkenheimer valves are made especially long, so as to give plenty of threads to take a full depth pipe thread.

In the Lunkenheimer Renewo valve the difference in construction is in the disk and seat. The disk is provided with a projecting ring which enters the valve seat ring, deflecting the current of steam from the seat ring face and thus preventing wire drawing and cutting of the seat, the thin current of steam blowing off all scale or grit which might have lodged there. This projecting ring also admits steam gradually to a pipe, thus preventing water hammer. Both seat and disk are renewable, but the seat may be reground a number of times before it has to be renewed.

The bonnet is held to the body of the valve by a union ring and in this type of valve the bonnet carries the guiding thread for the stem. The same repacking feature is used as in the regrinding type.

In the Clip double seated gate valve, pressure may enter from either end and the valve can be connected

in any position. The body is rigid, which gives little liability of the springing of seats. The bonnet is held to a packed seating by a clip which passes around the body of the valve, thus avoiding any possibility of leakage from expansion. The joint between bonnet and body is made by a copper wire gasket which beds partially in the top surface of the valve body.



RENEWO VALVE WITH RENEWABLE SEAT AND DISK

These valves are made either with iron body brass mounted or with all iron body, as may be desired.

In the Victor gate valve 2 forms are made, one with stationary stem and the other with outside screw; in the latter form a yoke is used for carrying the hand wheel. Seat rings and wedge disk can be renewed when worn, the seat rings being faced off straight so that when screwed in place they fit accurately to the taper of the disk.

For sizes up to and including 6-in. valves the disks are entirely of bronze. Above this size they are made

FIG. 1. TWO DISCS AND WEDGE OF THE NELSON IRON GATE VALVES

FIG. 3. EXTERIOR OF MEDIUM SIZE NELSON IRON GATE VALVE

of iron with bronze seat rings. The same repacking under pressure feature is found as in other types of valves, also the joint between bonnet and body is made with copper wire gasket, as in the Clip valve.

THE NELSON GATE VALVE, WITH TAPERED DOUBLE DISCS.

The Nelson Valve Co., Chestnut Hill, Pa.

THE ESSSENTIAL FEATURES in this valve, it is claimed, lie in a combination of simplicity with strength and efficiency.

The manufacturers point out that the disc and wedge mechanism is very simple, composed of 3 parts only, as shown in Fig. 1; these are also shown assembled in Fig. 2, an inside view of an iron valve, open, and the same valve closed.

In the bronze valve the same principle is followed, with some minor changes in the shape, as in Figs. 4 and 5.

Because they are so simple, the discs require only a small space, so that the body of the valve is short, compact, and consequently strong.

By making the disc double, and by tapering the seats of the valve, the manufacturers claim that the valve

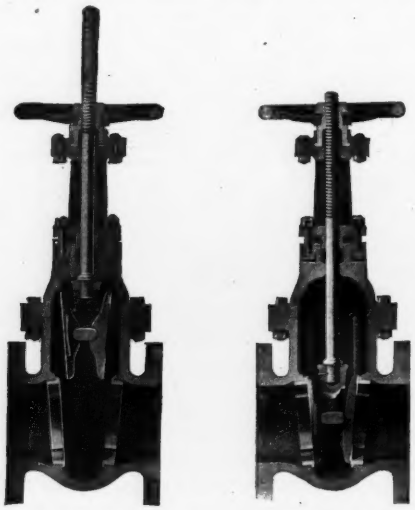


FIG. 2. INSIDE VIEWS OF NELSON IRON VALVE, OPEN AND CLOSED

holds tight under the hardest working conditions; that violent changes in temperature, distortions of the valve body, either permanent or temporary do not prevent the valve from holding the fluid tightly; as an extreme instance of the flexibility of the disc mechanism, a valve is shown, Fig. 5, in which a nail has been jammed between one disc and seat, but the disc on the other side holds the pressure as well as if both discs were in action. This is because they have a large freedom of movement, automatically rocking into the position required for perfect seating.

It is also a feature of these discs that they are so simple that they can not get out of order if the valve is attached upside down or in any unusual position, and that, when taken apart for inspection, there is no danger of putting them together wrong.

The discs operate in guides in the valve body, sliding freely up and down; when all-the-way-open, they are entirely out of the path of the fluid and give as large and free an opening through the valve as through the pipe to which it is connected. The guides also support the discs in such a way as to prevent the wabbly action known as "chattering," and keep the discs from binding on the stem or elsewhere, allowing easy operation.

The manufacturers also call attention to the curved shape of the valve body, which they claim, gives an ex-

ceptionally good casting and provides great resistance to the powerful fluids that valves must safely hold; the valves are tested at the factory to more than double the pressure that they will have to hold in actual service.

Provision is made for all pressures required in power plant service, a "Standard" valve being made for working pressures up to 125 lb., a "Medium" valve for 175 lb. working pressure, and an "Extra Heavy" for pressures up to 250 lb.

For superheated steam, which is coming more and more largely into service now, the Nelson Valve Co. makes its Steel Valve, built along the same lines as its iron valves, but with some special features to meet the extraordinary demands of this service.

The original disc mechanism has been found to be all that is desired, and has been utilized without change. The bonnet is made with an extra long condensing chamber to cool the valve near the stuffing box, and cork-handled hand wheels are provided so that the extreme heat will not burn the operator's hands.

FIG. 4. NELSON STANDARD BRONZE GATE VALVE, INSIDE AND EXTERIOR

FIG. 5. NELSON BRONZE GATE VALVE WITH NAIL JAMMED BETWEEN DISC AND SEAT

The main castings are made of open hearth steel, from patterns especially designed to get every pound of strength obtainable; but, on account of the erosive action of superheated steam, a nickel alloy, known as Monel metal, is used for the working parts. This, the makers say, has proved a happy combination of metals for superheated steam valves, as both are more than 65,000 lb. per square inch strong, and both expand and contract in such perfect unison that there is no leakage, even at extreme temperatures.

OHIO VALVES

Ohio Brass Co., Mansfield, Ohio

THE OHIO GLOBE and angle valves are made up in 3 grades, heavy standard, standard, and standard No. 2, commonly known to the trade as competition grade. Distribution of the metal is such as to give a maximum of strength where most needed, and to give long life and dependability. All valves are fitted with large fluted iron hand wheels and have disks and seats designed to give the greatest amount of wear. The disks are renewable and have spherical surface so that they seat readily under all conditions.

Besides these valves the Ohio Brass Co., makes a full line of bronze fittings of heavy standard dimensions, including elbows, tees, Y's and unions, and a standard lock and shield globe valve for locations where it is desirable that the valve shall not be opened except by persons properly authorized to do so.

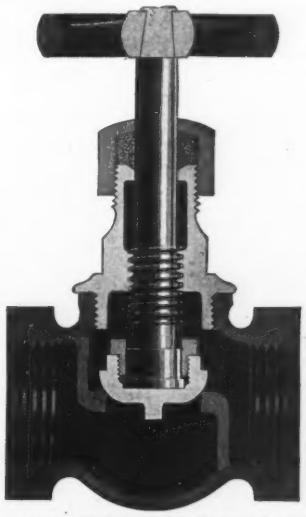


FIG. 1. OHIO HEAVY STANDARD GLOBE VALVE

OSBORNE VALVES

Osborne High Pressure Joint and Valve Co., Chicago, Ill.

THE OSBORNE VALVE in opening or closing, performs 2 operations, viz: shuts off the flow or pressure to almost nothing; permits the valve to seat under either a balanced, or greatly reduced, pressure. The wire-drawing is thereby transferred away from the seats to the surfaces provided for that purpose, located on the extension to the disk and on the seat-ring or body.

The figures p. 88 show the valve in 3 positions, and when just opening or closing, at which time the seat is protected by the disk-extension or protector D, which holds the flow in check, and the expansion chamber E located between the seats and the protector, which keeps the pressure across the seats equalized, or greatly reduced. The area A between the valve seats is then many times larger than the area B between the protector and the seat ring, which is a slip fit; consequently the wear comes on the protector and the seat ring provided for this purpose, and not on the valve seats proper.

The high-pressure, iron-bodied valve with flanged ends, shown in section is in operation at pressures ranging from 5 to 3,000 lb. and is made of iron or brass, with either flanged or screw ends.

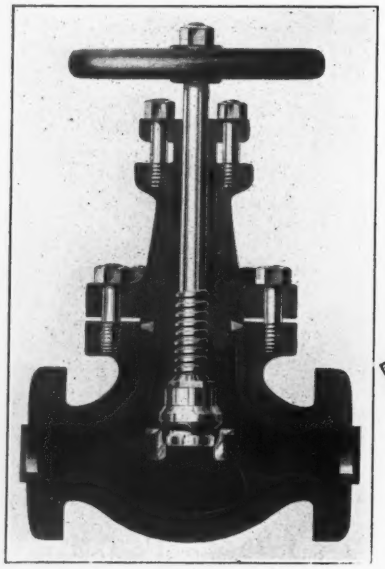
CLEAN SEAT VALVES

Pittsburg Gauge & Supply Co., Pittsburg, Pa.

CONSTRUCTION OF THE clean seat valve is shown by the section view of the valve and seat, and the operation by the sectional view of the angle valve. In closing, the Clean Seat valve throws a strong jet of steam directly across the seat and disk faces all the way around, thus blowing off any sediment which might prevent tight closing. Just at the moment of closing, a hollow cylindrical extension beneath the disk

fits loosely in the seat opening, this forming a narrow slot below the disk face, and forcing the throttled flow between the disk and seat under full pressure. This jet continues to flow until the final moment that the closure is completed.

By giving the lugs which support the extension of the disk a spiral form, the jet turns the disk on the



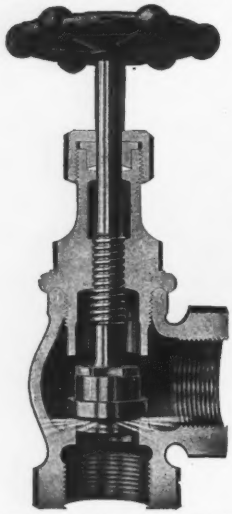
SECTION OF IRON BODIED OSBORNE VALVE WITH FLANGED ENDS

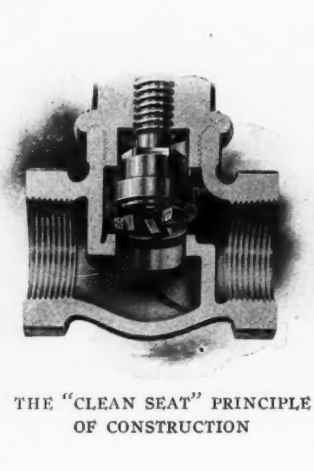
spindle each time that it is closed, thus giving a new seating and giving the steam a whirling motion as it issues through the slot.

STEAM VALVES

Wm. Powell Co., Cincinnati, O.

THREE TYPES OF globe valves are made by this company and are known under the names of White Star, Model Star, and Union Disc.



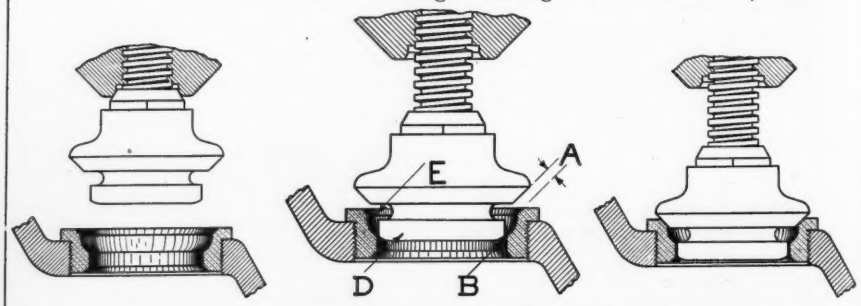


THE "CLEAN SEAT" PRINCIPLE OF CONSTRUCTION

CLEAN SEAT ANGLE VALVE SHOWING ACTION OF THE STEAM JET

The distinctive construction feature of these types is that no flat faces are used in the connection between body and bonnet, thus obviating the necessity of red lead or other cementing material to make the joints steam tight. By the illustrations it will be seen that the connection between body A and bonnet N is a beveled ground face union which is secured by the large hexagonal nut a, the effect of this construction being that the harder you wrench down this hexagonal nut, the tighter is the contact made. It also has the tendency to expand the threads making them bite all the harder.

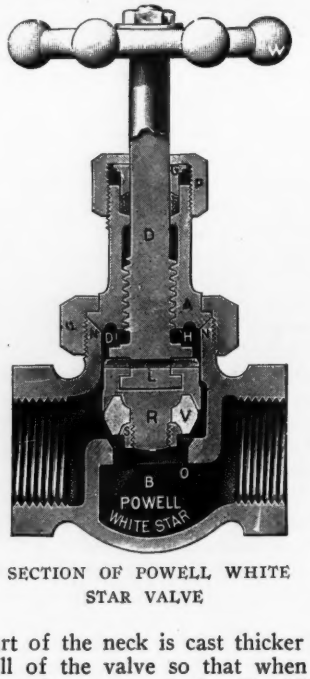
There is an extra thickness of metal cast on the body neck of the Powell valves for chasing the threads and forming the beveled faced seat, assuring full perfect thread and retaining the strength of the neck walls, which



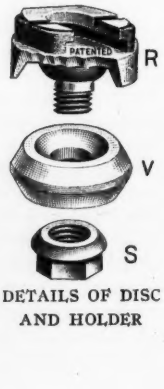
OSBORNE VALVE AND SEAT, WIDE OPEN, JUST OPENING, AND CLOSED

might be weakened were the threads cut directly into them and not, as is done in this design, into a special thickness of metal cast with the body casting for this purpose.

Wherever there is liability of a strain, either by incorrectly supporting the valve, or the natural strains of service, strength has been added to the body. The lower



SECTION OF POWELL WHITE STAR VALVE

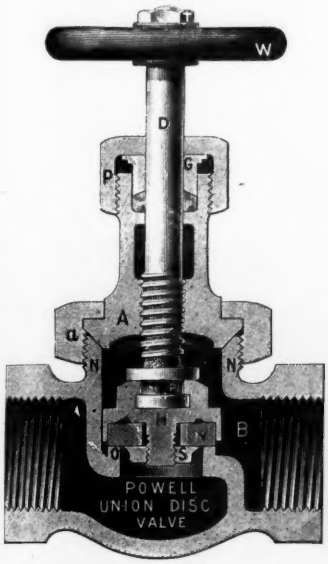


DETAILS OF DISC AND HOLDER

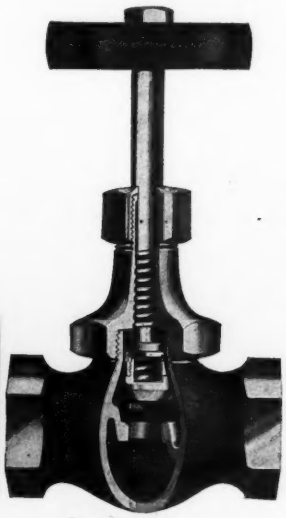
part of the neck is cast thicker than the bottom of the ball of the valve so that when the valve may be improperly supported the "buckling" of the diaphragm caused by the strain of the weight of the pipes is prevented for as long a time as is reasonable, according to the stress placed on the valve by the weight of the length of the pipe it may be trying to support.

The special feature of the Powell White Star valve is found in the disc. This is reversible and renewable, thus reducing the cost of maintenance to a minimum. The metal used in the contsruction of the disc is a hard, close-grained white bronze or "Powelium Bronze." The melting point is high, and the materials that enter into its composition are such as to form a bronze of great durability.

It can be reground as often as desired, yet is hard enough not to "pit" whenever a particle of scale or other hard substance is met when seating. The disc and seat construction being at an angle also safeguard the valve



POWELL UNION DISC VALVE



LAMB SELF-GRINDING VALVE IN SECTION

as it is almost impossible for grit to lodge on the seat, the force of the steam when closing down the valve blowing these particles off.

The disc is carried in the disc holder R, which protects one face while the other is in service. The disc holder slides between the forcing collars and is readily removed whenever it becomes necessary to reverse or renew the disc.

When one side of the disc is entirely worn out, the disc holder can be locked in a vise by means of the flat sides, loosen nut S, lift out and reverse the disc. After which the nut is replaced on its steam and the disc holder returned to its position between the forcing collars on the stem and the reversed face should then be reground to a new seat.

The Powell Model Star valve is the regular bronze regrinding valve and combines the same features of body construction as are found in the White Star valve, and is cast of the same bronze composition as is specified by the U. S. Government for its naval and Panama Canal service.

The disc of this valve is made of the same material as the body and trimmings and in the 1-in. and larger sizes, swivels on the stem. It can be reground to a new seat whenever desired, thus prolonging the life of the valve.

The Powell Union Disc valve is so named from the vulcanized composition disc which is used in place of a bronze disc. This form of valve is preferred by some engineers on account of the facility with which a disc can be replaced and the low cost of these discs. The same constructive features are followed in the body and trimmings as are found in the other styles of Powell Globe Valves.

The Powel valves are also made with iron bodies with yoke tops from 2 in. to 8 in. These styles combine the accepted designs of the best practice with the various special features of each type of valve.

THE LAMB SELF-GRINDING VALVE

Valve Sales Co., LaCrosse, Wis.

THIS VALVE IS MADE for pressures up to 150 lb. of Swenson metal especially distributed to give the greatest strength, and is provided with a self-grinding disk, the feature of which is the small internal steel spring which compresses when the valve is being closed until the base of the stem rests solid against the base of the disk. When opening the valve this spring expands, and furnishes the necessary pressure for another regrinding operation. Disk and seat are beveled so as to afford little lodging place for grit, and the grinding operation forces out any that may catch there. At the end of the stem is a collar which seats against the bottom of the bonnet, thus permitting repacking of the valve stem under full steam pressure.

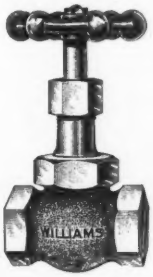
The bonnet screws over the outside of the body and is especially heavy, thus tending to keep this joint tight as the body expands. Every valve is tested to 500 lbs. under and over the seat.

Another valve made by this company is the Swenson, which is built for pressures up to 200 lb. In this type the spring which forces the disk to its seat is embodied in the bonnet, but the same principles of construction are employed as in the Lamb valve.

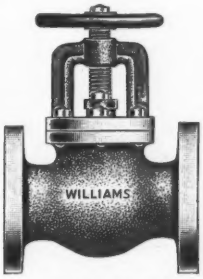
WILLIAMS VALVES

The D. T. Williams Valve Co., Cincinnati, Ohio

THESE ARE MADE in both globe and gate form, the globe valve being of regrinding type and arranged so that it can easily be repacked when under pressure. The standard service valve is suitable for pressures up to 200 lb. and the extra heavy pattern up to 350 lb.



WILLIAMS BRASS REGRINDING GLOBE VALVE



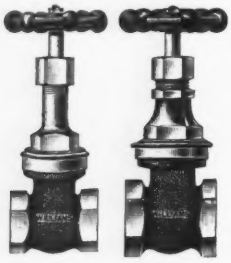
WILLIAMS IRON BODY STOP VALVE

In the gate valves 2 forms are made, one having 2 disks which are suspended from a rising stem between tapered seats and with ball and socket bearings between the disks to distribute the pressure uniformly on the seat. The other style has a solid wedge disk carefully fitted to tapers of the seat and is operated by a stationary stem.

For quick opening, lever throttle valves are provided, these being especially adapted for use on saw mill, hoisting and traction engines where a heavy quick opening valve is neecssary.

For pressures up to 175 lb., iron body stop valves are provided with screw stem and yoke as indicated and

having either flange or screw ends as desired, and for those who prefer a less expensive valve the iron body



WILLIAMS WEDGE DISC GATE VALVE AND DOUBLE DISC GATE VALVE

QUICK CLOSING LEVER VALVE

valve is made in the plain pattern with bonnet and without yoke.

DAVIS VALVES

The G. M. Davis Regulator Co., Chicago, Ill.

THE DAVIS PRESSURE regulator is an automatic valve for reducing the pressure of steam or air from any initial pressure to any delivery pressure, its operation being controlled entirely by the delivery factor. It is weighted to the pressure desired, and maintains the delivery pressure constant, irrespective of the variation in the initial pressure, but will not of course reduce against a dead end.

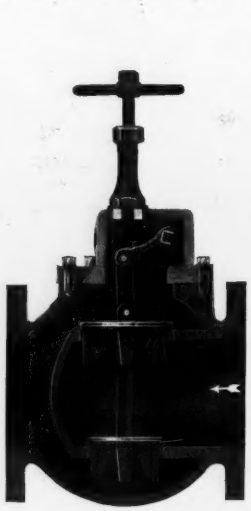
FIG. 1. THE DAVIS PRESSURE REGULATOR

Steam enters the high pressure chamber and passes through the seat into the cylinder, tending to force the piston upward and draw closed the inner valve to which it is attached by a link. This tendency is counteracted by weights suspended from the lever which is connected to the piston by a yoke and stem on the outside, and balance is thus established between steam pressure and weight.

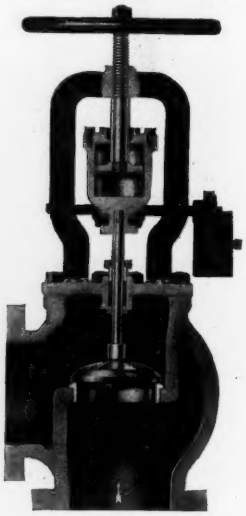
If the delivery pressure increases, it forces the piston upward closing the inner valve somewhat, and throttling the pressure down until a balance is again reached. If the delivery pressure decreases, the weights carry the piston down, opening the inner valve wider, and the pressure under the piston increases until it again balances the weights. If more weights are suspended from the lever the delivery pressure is increased, and vice versa. Around the piston are a series of rectangular grooves cut on the outer surface and extending the entire length and the piston is ground to fit the cylinder perfectly so that the grooves catch steam which tends to escape and condense it, forming a water packing, thus effectively preventing excessive leakage. This gives a packing which operates without friction and is therefore extremely sensitive. It also makes the use of metallic or fibrous packing unnecessary.

The inner valve of the pressure regulator is carefully designed to give perfect balance at every point of its travel and under all pressures, being made up of 3 disks, the top one of which acts as a balance plate.

In the class A, Automatic Non-Return Valve, which in the illustration is shown in the globe pattern, but which is also made in an angle pattern by the G. M. Davis Co., admission or inlet is as shown from the bottom, and the pressure forces the disk away from the seats, allowing the steam to pass through the ports to the outlet at the top. If the valve stem be screwed down it, of course, forces the disks to their seats and closes the valve. If again the steam pressure fails on the inlet end of the valve and is kept up on the outlet end, the pressure will act on the top of the disk and will force the valve closed, and as the area of the upper disk is greater than that of the lower the valve will remain closed. The weighted lever also tends to throw the valve shut, if steam pressure on the inlet side fails at any time. This weighted arm also serves as an equalizer to insure that each unit emptying into a header shall be kept up to the average pressure.



DAVIS AUTOMATIC NONRETURN VALVE, CLASS A



DAVIS STOP AND CHECK VALVE, CLASS C

In the class C, automatic stop and check valves a different design is used, although the valve is for the same purpose as class A. The dash pot is put outside the valve body where it cannot be caused to stick by the heating of the steam, nor can it accumulate scale or deposit.

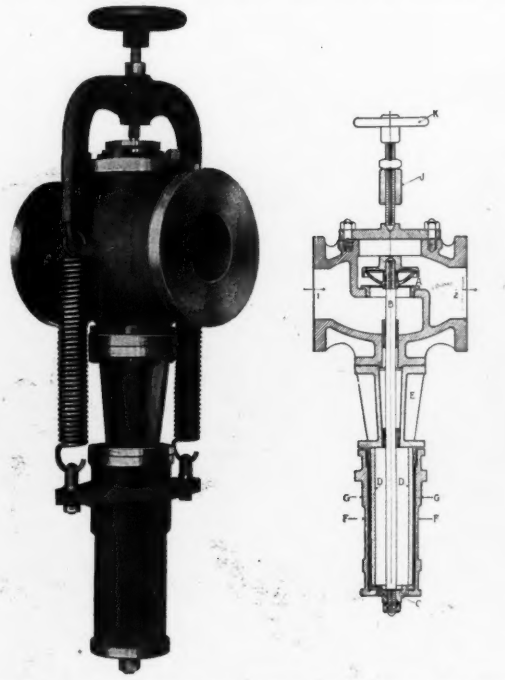
Inlet is from the bottom and forces the valve disk upward against the weight which is shown at the right hand side of the arm. This weight acts by

fingers against a slotted yoke to hold the valve closed, and if the pressure on the inlet side fails, the pressure on the outlet side, together with the weights, will throw the valve shut and hold it there. The oil dash pot above tends to prevent fluctuation and chattering of the valve. The valve is forced closed by screwing down the hand wheel and thus setting the stem against the bottom of the dash pot chamber.

ELLIOTT REDUCING VALVES

Elliott Co., Pittsburgh, Pa.

AS SHOWN IN THE exterior view and cross section illustration which are for the type A valve, the steam passes through the valve as indicated by the arrows, the high pressure entering at 1 and the reduced pressure issuing at 2. The main steam valve A is connected by spindle B to a tube cased cap C, which surrounds the India rubber tube D, resting in the bottom as shown. The India rubber tube is reinforced on the outside by a



SIDE VIEW IN SECTION AND END ELEVATION OF ELLIOTT REDUCING VALVE TYPE A

number of rings, which permit the tube to stretch only in the direction of its length, keeping it of constant diameter, and at the same time preventing any friction by the tube coming in contact with the tube case G.

At the upper end of the tube case are wings to receive the upward pull of the springs I, shown in the exterior view. These springs are put in tension by the yoke and the adjusting screw. The amount of pull on these springs will therefore determine the amount of pressure. As soon as the pressure on top of the valve from the low-pressure side overcomes the pull on the springs, the India rubber tube will commence to stretch and allow the valve A to close, thus preventing further passage of steam.

As a relief, the top valve, which is of some 20 per cent less diameter than A, is held down by the screw K, and if the low-pressure side becomes too great, the valve will relieve the excess pressure, thus avoiding over pressure on the low-pressure side, if any reason, such as dirt, under the main valve, prevents the closing of the valve A.

The rubber tube is protected from the action of the steam by being filled with condensation water.

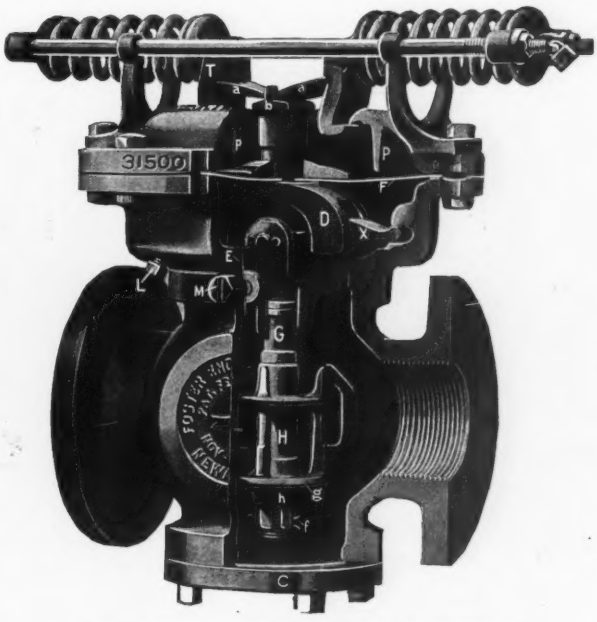
The Elliott Reducing Valve is a combined safety and reducing valve and is built in sizes from ½ to 4 in.

FOSTER VALVES AND REGULATOR

Foster Engineering Co., Newark, N. J.

IN THE AUTOMATIC nonreturn stop valve the valve disk is mounted on a stem which carries at its upper end a piston working in a dashpot cylinder. The valve is held to its seat by means of a handwheel and screw. When this stem is raised, the valve is free to rise from its seat under the force of pressure from below. Inlet is at the bottom of the valve, and outlet at the side.

When the boiler pressure is 1 lb. or more greater than the pressure in the header, the valve lifts and is held open by the flow of steam passing through the



FOSTER AUTOMATIC NONRETURN STOP VALVE

valve. If the boiler pressure falls below that in the main, the pressure, acting on the upper side of the valve, will force it to its seat.

In the Foster Combination Valve, 4 valves are combined in one—it acts as an automatic nonreturn stop valve, an automatic emergency stop valve, an automatic safety stop valve and a hand stop valve. As a nonreturn stop valve, its operation and interior construction are the same as described above. A large cylinder containing a piston is mounted on the top of the valve. This piston is operated by means of a pilot valve, whose inlet is connected to the drum or header, and the outlet to the top of the cylinder. A connection is made from the diaphragm chamber of the pilot valve to the main line.

As an automatic stop valve in the event of rupture in the main line, steam will be admitted through the pilot valve and on top of the large piston, thus closing the main valve and preventing further flow of steam from boiler or boilers. Small emergency pipes may

be connected to the diaphragm chamber of the pilot valve and run to different parts of plant. When desired, the main valve can be closed by opening a small globe valve in the emergency lines. The handwheel on top is used to close it in the same way as an ordinary stop valve.

The Foster Pressure Regulator is controlled and operated by the movement of a diaphragm opposed to the action of springs, whose tension is adjusted to maintain a constant delivery pressure, regardless of any variation in the initial or supply pressure. A toggle and lever arrangement is interposed between this spring and diaphragm, compensating the movement of the diaphragm and the increasing power of the springs under variable degrees of compression.

Steam enters at the inlet side A, and flows through the valve to the outlet side D. In its course it enters the chamber beneath the diaphragm through a port from the outlet side of the valve. Any increased pressure on the diaphragm overcomes the resistance of the springs and lifts the valve towards its seats, thus throttling the flow of steam. Should the delivery pressure decrease, the springs overcome the pressure on the diaphragm and force the valve open.

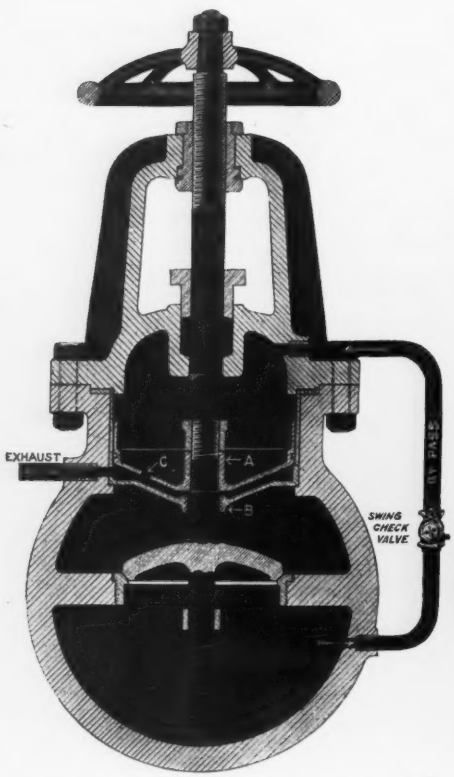
The delivery pressure is controlled by adjusting the nuts on the ends of the spring rods at the top of the valve. A port screw is used for throttling the port leading from the outlet side of the valve to the diaphragm chamber. A peculiar feature of this type is that it operates practically without friction, as the internal parts are very loosely fitted.

GOLDEN-ANDERSON VALVES

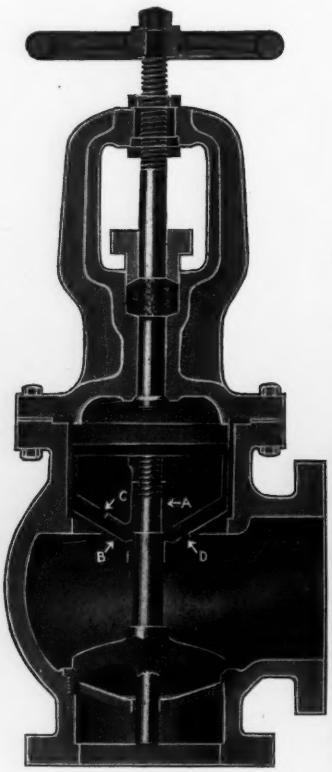
The Golden-Anderson Valve Specialty Co., Pittsburg, Pa.

IN THE TRIPLE-ACTING, double extra heavy valve, the entire upper portion of the valve body is used as a cushion for these valves in opening or closing. The disk is of arched form with a 45 deg. seat, this seat being renewable. The upper end of the valve stem is threaded into the yoke but is detached from the lower end of the valve stem so that the valve is free to rise and fall with the action of steam pressure. By means of the bypass pipe, full steam pressure is taken from below the valve to above the dash pot A, and this passes through the opening C, so that it is also below the dashpot. The part B is a bronze cylinder held to the valve body by means of the valve bonnet.

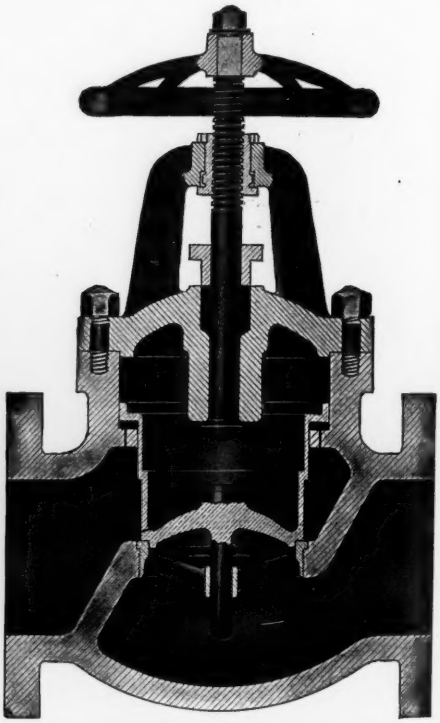
If a rupture occurs in the steam lines which are connected to the valve above the disk, the boiler pressure will tend to throw the valve wide open, and this will exhaust all steam pressure from beneath the dashpot. Full boiler pressure is maintained above the dashpot A by means of the bypass, and this acting on the dashpot will force the valve to its seat, and hold it there as the area of dashpot A is larger than that of the valve disk. The automatic pilot valve used to exhaust steam from between the 2 parts of the dashpot is simple in construction and can be set for any variation of pressure desired in the outlet end of the valve. In case pressure in the boiler falls below that in the mains, the higher pressure will act



GOLDEN CUSHIONED NON-RETURN VALVE



SECTION OF GOLDEN TRIPLE-ACTING AUTOMATIC VALVE



ANDERSON CUSHIONED CHECK AND HAND STOP VALVE

on top of the valve, and throw it to its seat. It will be cushioned by the steam below the dashpot.

In the Golden cushioned nonreturn valve the same Corliss dashpot method of cushioning is used as in the triple acting, but this valve does not provide for cutting off in case of a break in the steam mains. The valve is free to rise and fall when the upper part of the stem is screwed upward, and so long as boiler pressure from below is on the valve, it will be held open. If boiler pressure fails, the valve will be forced to its seat, by pressure from the main, but will be cushioned by the action of the steam between

ECLIPSE REDUCING VALVE

the 2 parts of the dashpot. In the case of opening the valve, the disk will be cushioned by the action of steam in the chamber above the dashpot.

Golden valves are made of cast iron, steel or semi-steel, and fitted with brass, bronze or nickle bronze in accordance with the specifications of the purchaser.

In the Anderson cushioned check and hand stop valves, the operation may be made a check in either direction, that is, against fall of pressure in the boiler, or against bursting of a steam main as desired. The valve should of course fall against the direction from which steam ordinarily flows, so that if the pressure on the top becomes higher than that at the bottom the valve will close. The steam caught in the chamber above the valve acts as a cushion to prevent chattering of the valve either in opening or closing.

ECLIPSE VALVES

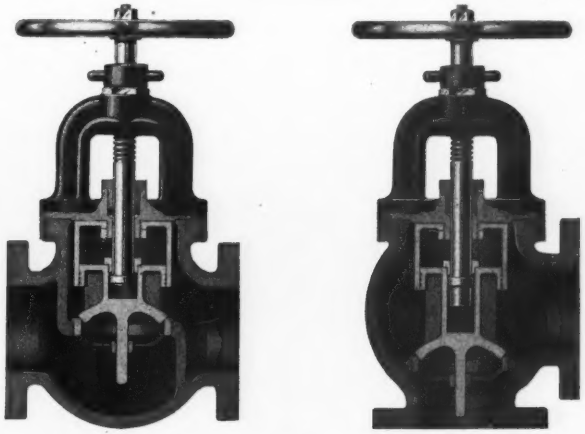
Hughson Steam Specialty Co., Chicago

THE OPERATION OF the reducing valve is extremely simple and is almost obvious from inspection. Steam enters from the right-hand end and passes upward and downward through the valve, which has 2 disks balanced, so that there is no tendency for the valve to open or close; but the low pressure in the left-hand chamber acts upward on the end of the valve stem and on the bottom of the piston, which works in the upper casing.

As the pressure on the outlet or left-hand side rises, it tends to force the valve upward against the weight shown at the end of the arm in the exterior view, and the valves are thus closed to the point where the back pressure balances the effect of the weight. By changing the weight on the pan, back pressure may be regulated as desired. The dashpot attached to the weight arm prevents sudden fluctuations.

In the Eclipse stop and check valve, which is here shown in globe and angle patterns, steam enters from the bottom and passes to the right. The valve is free of the stem and when the stem is screwed upward, pressure from beneath will force the valve open and will hold it open so long as the steam continues to flow. The upper part of the valve carries a piston working inside a casing which acts as a dashpot.

If pressure on the inlet side should fail, the pressure on the outlet immediately acts on top of the



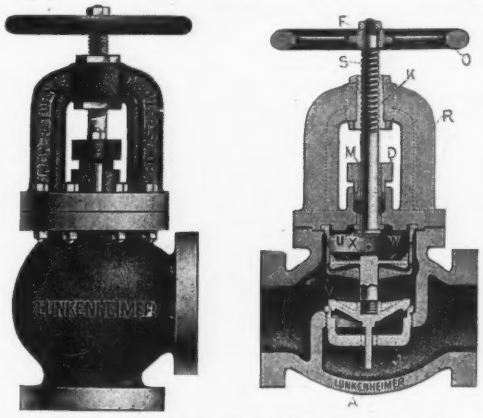
ECLIPSE AUTOMATIC STOP AND CHECK VALVE

valve disk to force it to its seat, thus preventing flow of steam in the wrong direction. The valve is, of course, held closed by screwing down the stem, which then comes in contact with the upper surface of the valve disk and holds it closed. The manufacturer states that the wheel should be set down or in a horizontal position, as this assists in preventing chattering.

LUNKENHEIMER NON-RETURN BOILER VALVE

The Lunkenheimer Co., Cincinnati, O.

In the Lunkenheimer Non Return Boiler Valve, all wearing parts are of bronze and gland and stuffing box



THE LUNKENHEIMER NON-RETURN VALVE

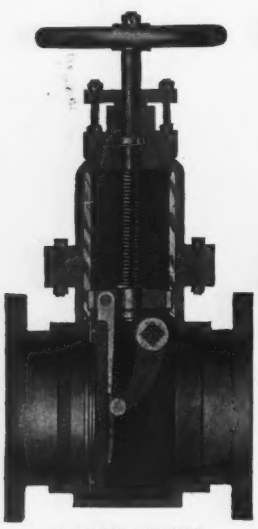
are of bronze bushed. For superheated steam the valves are of puddled semi-steel with nickle trimmings and nickle-steel stem. The valve operates on a stem which has at the upper end a piston working in a cylinder and

acting as a dash pot, so that when the valve wheel is turned upward the valve is free to rise and fall with the pressure coming from the under side as it passes out of the boiler. For closing the hand wheel can be screwed down and the valve will then be held positively to its seat. In case of failure of boiler pressure, the pressure from the main, acting on the upper side of the valve disk, throws it closed and holds it there. This valve is made in either angle or straight through form as shown in the illustration.

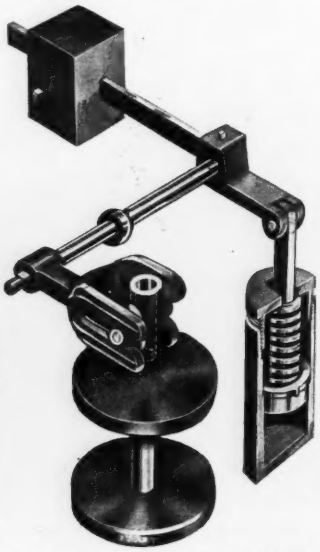
THE ERWOOD STRAIGHTWAY SWING GATE VALVE

Walch & Wyeth, Chicago, Ill.

IN THE ERWOOD Swing Gate valve features are embodied which give it special advantages. It is a gate valve in action, closing with a sliding contact of the valve against the valve seat, and the valve disk is held in position by springs attached to arms



ERWOOD SWING GATE VALVE



MECHANISM OF LAGONDA VALVE

outside the valve body. The tension of these springs may be regulated to any pressure desired. When the valve is open there is no obstruction in the pipe and the valve is noiseless in operation.

If the pressure on the seat side of the valve becomes greater than that for which the valve is set, it will swing open as a check and permit the pressure to relieve, but steam never passes through the valve in the opposite direction no matter how great the pressure may become. It therefore becomes a relief valve or a nonreturn valve which is automatic in action, will work in any position, and can be regulated for any pressure.

When used as an automatic nonreturn valve, it should be set so that the current in normal operation is against the face of the valve. The construction and method of operation are clearly indicated in the sectional view which shows the valve disk slightly raised from the seat.

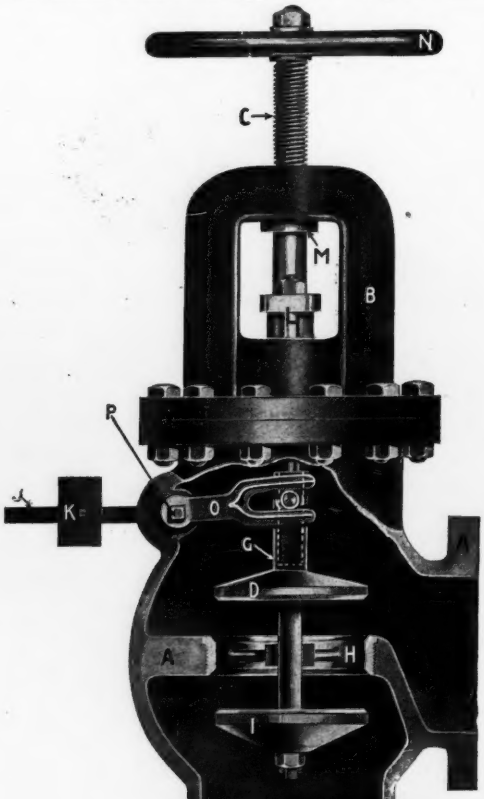
LAGONDA AUTOMATIC CUT OFF VALVES

Lagonda Mfg. Co., Springfield, Ohio

BY TURNING THE handwheel down, this may be used as a stop valve, and when the wheel is turned up, it is entirely automatic as a cutoff valve and will close as soon as pressure fails on either side. The valve is made in either straightway or angle form, and can be left in line, simply opening and closing according to requirements of steam pressure if so desired. When used on top of a boiler the upper valve rests upon the seat so long as the boiler is shut down, and prevents steam from flowing into the boiler from the main.

This closure takes place automatically when the boiler is shut down, the valve remaining closed until the boiler pressure slightly exceeds the pressure in the main. The disks are very nearly balanced by the weight and with a slight flow of steam will rise to normal position where they remain so long as steam is drawn from the boiler.

If a break occurs beyond the valve, the excessive rush of steam will carry the lower disk up against the seat, shutting off the boiler, and if any excessive reverse flow of steam occurs the upper disk drops instantly to



SECTION OF LAGONDA AUTOMATIC CUTOFF VALVE, ANGLE TYPE

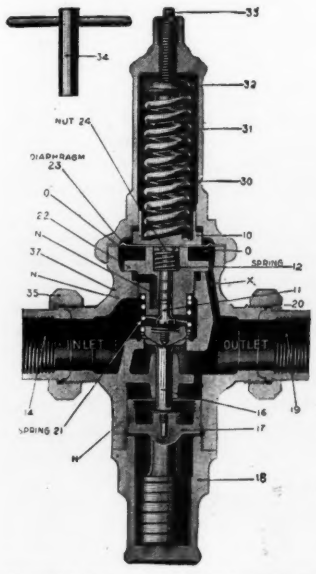
its seat shutting off the main. With the valve standing in normal position, the area through which steam flows is large so that the disks interfere in no way with this flow, and the difference of flow at which the valve will close is determined by the adjustment of the balance weight on the arm and the dash pot.

Valve disks, weight and dash pot are shown in a separate illustration which makes clear the relation between them and the method of action. As the weight arm is positively connected to the disks, the valve can be closed in either direction by moving this arm from the outside. The dash pot prevents chattering due to pulsation from the steam flow, and cushions the disks as they seat, thus making the operation noiseless. In installing the valve the lower disk should be toward the boiler with the handwheel on top.

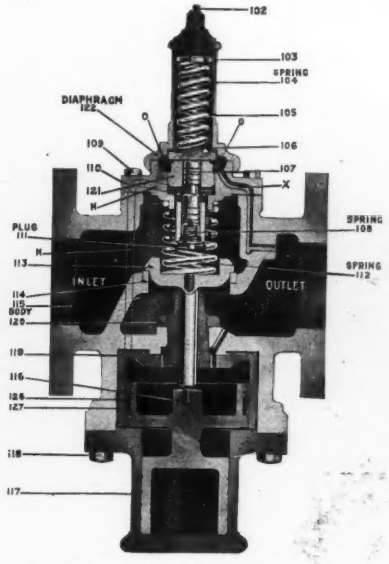
MASON REDUCING VALVES

The Mason Regulator Co., Boston, Mass.

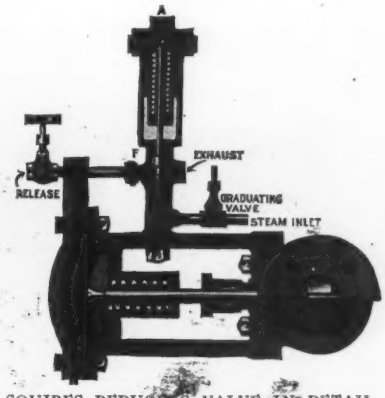
THE STANDARD REDUCING valve is controlled by variation of the reduced pressure acting through the port X on the diaphragm 23. Upward motion of this diaphragm is resisted by the spring 31 in the upper chamber which can be adjusted by screw 33 for any desired pressure. Thus an increase of the pressure in the outlet or reduced pressure side will force the diaphragm upward and permit the balanced auxiliary valve 11, which is forced upward by the spring 12 to close shutting off the admission of steam from the auxiliary port N. The main valve will then be closed by the steam pressure from the inlet side, which will force the valve to its seat, assisted by the action of spring 21.



SECTION OF MASON ALL BRONZE REDUCING VALVE



IRON BODY MASON REDUCING VALVE



SQUIRES REDUCING VALVE IN DETAIL

If the pressure in the outlet side falls, the diaphragm will be forced downward by spring 31, valve 11 will be opened and steam pressure from the inlet will pass through port N under piston 17 and force this upward against the stem of the main valve 16 opening that valve and allowing steam to flow through to the outlet side. In actual operation the main valve does not open or close entirely with each slight variation in pressure, but takes a position which will furnish just the steam required to maintain the desired reduced pressure.

In the iron bodied reducing valve with flanged connection the principle of action is the same as for the bronze body valve, but details of construction are somewhat different, as shown by the sectional view.

Steam from the outlet side passes through port X to the under side of the diaphragm; until the required low pressure is reached this diaphragm is forced against the auxiliary valve 107 holding off its seat and admitting steam through small inlets to the auxiliary port N, through which it passes under piston 116 and raises it, thus opening the main valve against the high pressure steam and the pressure of spring 112. With increase of pressure in the outlet side diaphragm 122 is forced up, permitting auxiliary valve 107 to close, thus shutting off steam from piston 116 and allowing the spring 112 and the high steam pressure to force the main valve to its seat. Auxiliary spring 108 is to force the auxiliary valve upward against the diaphragm so that it will follow the movement of the diaphragm.

THE SQUIRES REDUCING VALVE

The C. E. Squires Co., Cleveland, O.

IN THIS VALVE the main diaphragm is made up of 2 disks of spring sheet brass slotted radially toward the center, and assembled with the slots staggered. A rubber diaphragm is used simply as a packing, but does not carry the strain of the steam pressure. This diaphragm is water sealed, so that it is not affected by the temperature of superheated steam.

As shown in the illustration, a pilot valve is used to control the action so that the delivery is independent of the high pressure side since the governing pressure for the pilot valve comes from the low pressure side. Inlet to the pilot valve is piped to the boiler pressure, and inlet A at the top of the pilot valve is connected to the reduced pressure side. The pilot valve is what governs the reduction in pressure, and by changing the pilot valve any main valve may be used to reduce from any higher pressure to any lower pressure in one reduction.

Through the connection A, the reduced pressure acts on the diaphragm of the pilot valve, forcing down the compression spring the tension of which is varied by an adjusting nut. If this reduced pressure at A overcomes the spring, the pilot valve in the chamber below is reseated, closing the outlet and steam from the steam inlet seeping past the bottom of the pilot valve stem, accumulates pressure on top of the diaphragm in the main valve, and forces the main valve to its seat.

If the reduced pressure at A falls and the spring forces the diaphragm upward, the pilot valve is opened, allowing the steam to exhaust from above the main diaphragm, and thus permitting the spring which is around the main valve stem to force that valve open. In operation there will always be a slight exhaust from the pilot valve showing that the valve is just off its seat and that the main diaphragm is holding the main valve open just enough to maintain the required pressure.

WATSON DIAPHRAGM REDUCING VALVE

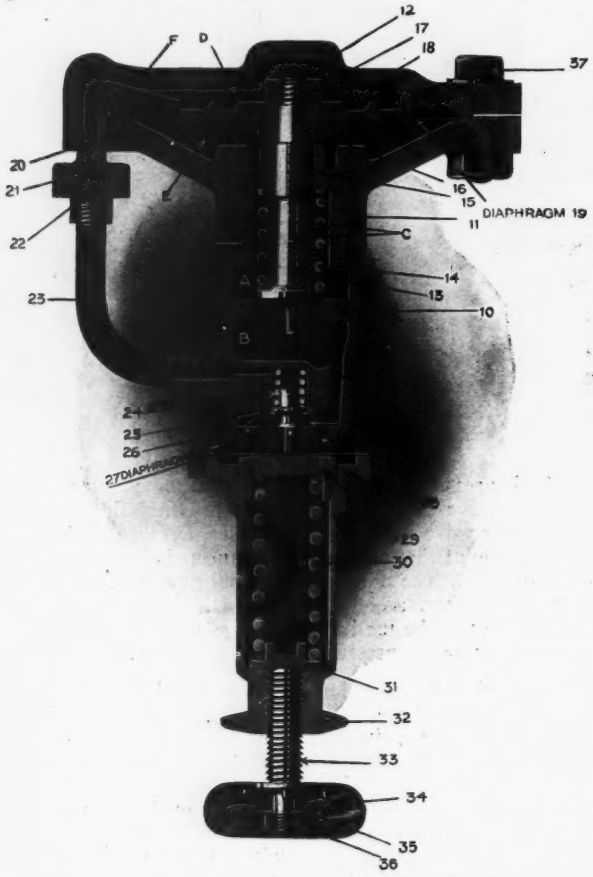
Watson & McDaniel Co., Philadelphia, Pa.

THIS WILL REDUCE from any pressure, 200 lb. or less, on the inlet to any pressure, from 20 to 100 lb. on the low-pressure side. It is made with balanced valves, controlled by a metal diaphragm, using compound levers to get full opening of the valve with slight movement of the diaphragm. Pressure is regulated by raising or lowering the regulating screw on top, thus changing the compression of the spring. Pressure from the outlet side passes through a port into the chamber in the valve bonnet, thus acting on the under side of the diaphragm. The diaphragm is of metal and all fits throughout the valve are loose, avoiding friction of working parts.

OHIO PRESSURE REGULATING VALVE

Ohio Brass Co., Mansfield, O.

WHEN INITIAL PRESSURE is first turned into this valve it enters at A in the sectional view, passing upward between the stem of the main valve 13, and guide nut 15, to the chamber E below the operating diaphragm, 19. At the same time it flows upward through port C in the stem of the main valve to chamber D above the operating diaphragm; from chamber D it is conducted by port F in the top cover of the valve and the small pipe 23 to the chamber above the controlling valve 25. Pressures are thus balanced on the diaphragm, and the steam pressure and spring 14 acting on top of the main valve hold it down on its seat.



SECTION OF TYPE F OHIO REGULATING VALVE

To put the valve in operation, the hand wheel 34 is turned slowly to the right, screwing it in, and thus compressing the regulating spring 30, forcing the controlling diaphragm 27 upward, thus lifting the controlling valve 25 from its seat and permitting steam to escape through ports G and H to the outlet on service side B, at the same time reducing the pressure in the chamber D, above the main diaphragm. Under these conditions the pressure on the under side of the main diaphragm 19, becomes greater than that above the diaphragm, and the diaphragm is lifted, carrying the main valve 13 with it and opening that valve for the admission of steam through the main ports to the service side B.

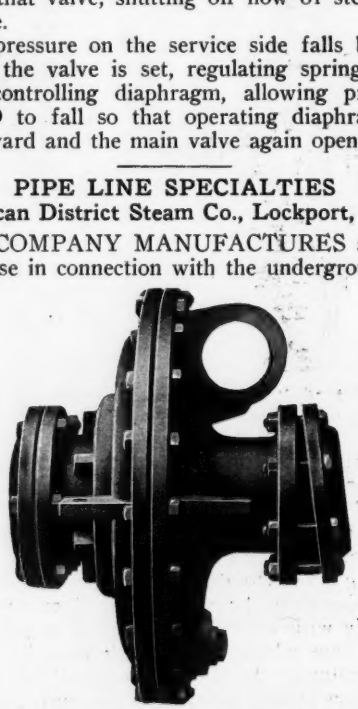
As pressure in B builds up it acts on the controlling diaphragm through ports H and J, and when this pressure becomes greater than that for which the valve is set, the controlling diaphragm 27 is forced downward, permitting the controlling valve 25 to close and shut off the escape of steam from chamber D above the operating diaphragm, 19. Pressure in that chamber then builds up rapidly through the ports in the main valve stem so that the pressures above and below the operating diaphragm are again balanced and the pressure of steam against the top of the main valve, assisted by the spring 14, closes that valve, shutting off flow of steam to the service side.

When pressure on the service side falls below that for which the valve is set, regulating spring 30 again lifts the controlling diaphragm, allowing pressure in chamber D to fall so that operating diaphragm 27 is forced upward and the main valve again opened.

PIPE LINE SPECIALTIES

American District Steam Co., Lockport, N. Y.

THIS COMPANY MANUFACTURES special devices for use in connection with the underground transmission of steam for heating and power purposes. To properly take care of expansion and contraction an ingenious device known as a "variator" is used. This



SINGLE EXPANSION VARIATOR OF AMERICAN DISTRICT STEAM CO.

SLIP EXPANSION JOINT

device is manufactured in 2 types—the single and the double, the single type being illustrated herewith. This device provides for the expansion and contraction of 50 ft. of pipe and is manufactured for pressures up to 100 lbs. The double form takes care of expansion and contraction of 100 ft. of pipe, 50 ft. on each side. The great advantage of this device for street work is apparent, from the fact that it does not require packing, the movement of the pipe being taken care of by heavy corrugated copper diaphragms.

The company also manufactures standard and special expansion joints of the slip type. They are of the regular packed gland type—iron body and brass slip, and the traverse varies according to requirements. They are made in sizes up to and including 30 in.

FLANGED 90-DEG. ANGLE JOINT

The flanged angle joint illustrated, is an ingenious device and enables any angle up to 90 deg. to be conveniently taken care of. These angle joints are made in any size up to and including 20 in.

The Holly steam meter, illustrated above, is designed and constructed to operate upon the velocity principle, and is built for any presure up to 75 lbs. It is simple in construction and does not interfere with the flow of steam. It soon saves its cost and therefore is a dividend earner.

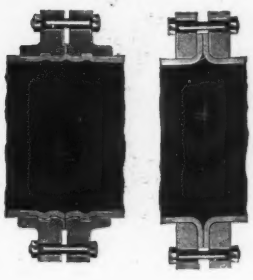
BEST PIPE FITTINGS

Best Mfg. Co., Pittsburg, Pa.

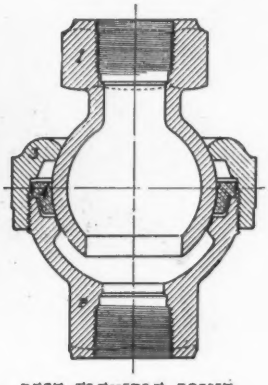
THIS COMPANY MAKES a full line of standard and special flanged fittings and flanges in bronze, cast iron, semi-steel, forged or rolled steel and malleable iron; also these fittings are made in the standard dimensions or of the long radius type.

For attaching flanges to pipe various methods are employed by the Best Company, the most used being the screwed joint refaced in the lathe is desired; the shrunk and rolled joint is made by shrinking the flanges on the pipe and then rolling the pipe over into a counterbore in the flange, after which it is faced off in the lathe; also the Van-Stone joint is made by rolling over the ends of the pipe at right angles and then facing in a lathe. This style of joint can be made with either the long hub or short hub flange and can be made recessed or male and female. The Van-Stone type of joint prevents any posible leakage between pipe and flange as the joints are made on the ends of the pipe abutting each other.

A specialty is flexible joints such as the Best type made up of 4 pieces, the ball, nut, ring and bell. The bronze seat ring can be replaced when worn, thereby avoiding the necessity of replacing the whole joint; also by reversing this seat ring the joint can be made a "tight" joint instead of a "flexible" joint. The Moran type of joint is made in 3 pieces, or the same as the Best joint without the bronze ring. These flexible joints are flexible under pressure and are desirable for service requiring a moving connection.

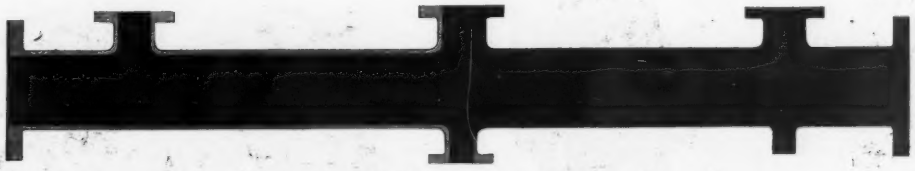


BEST SHRUNK AND ROLLED AND VAN STONE JOINTS



BEST FLEXIBLE JOINT

The Best Mfg. Co. makes pipe bends from the smallest pipe up to the largest lapweld pipe made, namely, 30 in. diam., and has improved facilities for bending to accurate dimensions on various radii and of any thickness of pipe with any kind of attaching of flanges. These bends are desirable for flexibility and freedom from leakage; they are also a factor in reducing friction, and for this reason it is desirable to make the radii as large as possible.



WELDED HEADER AND NOZZLES

The Best Co. also makes a specialty of welded headers, welding steel necks on steel pipe; also welding steel flanges on to steel pipe, thus saving in weight a number of fittings and also joints. One such header is illustrated herewith showing 4 flanged outlets and 1 screwed outlet.

Also we illustrate on another page the use of U bends with steel welded headers to take up expansion in large lines; this particular cut represents a 20-in. main line with 8x12-in U bends.

PIPE CUTTING AND THREADING MACHINES

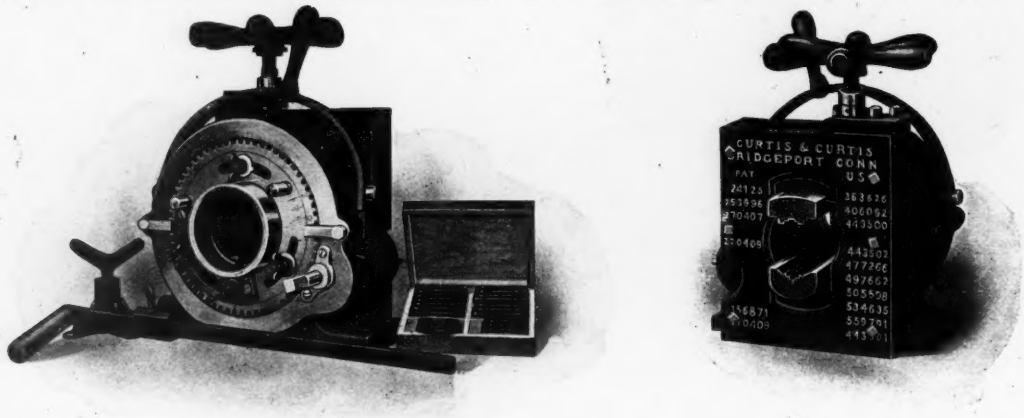
The Curtis & Curtis Co., Bridgeport, Conn.

THIS COMPANY MANUFACTURES the Forbes Die Stock illustrated herewith, which consists of a die carrying gear supported and surrounded by a shell, and

actuated by a small pinion embedded in the side of the shell, the pinion working on the large gear with the pipe vise, attached to the back of the machine.

To operate it, the pipe is placed through the pipe vise with the end to be threaded against the lead of the dies. The die carrying gear is then revolved by means of a crank on the end of the pinion; as the dies revolve the gear is drawn back into the shell, and the dies are thus brought onto the pipe. These dies are opening, and adjustable to any variations of fittings, and when the thread is cut, they can be opened and the pipe taken out without running back, or stopping the machine.

In cutting off pipe the gear is shoved back in the shell, and held by a stop, so as to give it a rotary without a traveling motion. A blade cutter is then inserted in the gear, which is automatically fed forward as the gear revolves. The cut illustrates the great advantage



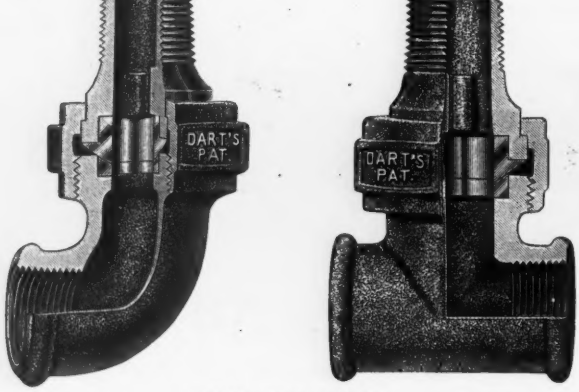
FORBES NO. 30 HAND DIESTOCKS, FRONT AND BACK VIEWS

of a revolving die head. As the pipe remains stationary, you can cut any pipe bend used in power plants, heating or plumbing contracts.

DART UNIONS

E. M. Dart Mfg. Co., Providence, R. I.

THESE ARE MADE up in standard union form with bronze, ball bearing seats and ground joints, but are shown in the illustration in the special forms which



DART UNION ELBOW
DART TEES WITH UNION ON RUN AND ON OUTLET

are combined with fittings. By using the concave-convex joints, the necessity of packing is done away with, and tight joints are assured, either in or out of alinement. In the patent elbow union is found a combination which serves as elbow, union and two nipples, and the same combination feature is found in the tee with union on either run or outlet.

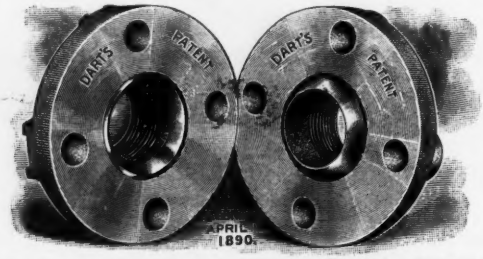
In the case of the flange joint the same principle of a spherical seat and nozzle is incorporated, giving the possibility of making up a tight joint with the pipe out of alinement. The seats are inserted and are of bronze as in the case of the union, so that they do not rust together.

CLIMAX STEAM JOINT CLAMPS

Jas. McCrea & Co., Chicago, Ill.

FOR REPAIRING LEAKS in steam pipe where the pipe is screwed into a fitting, the Climax clamp avoids the necessity of shutting down the plant, taking down the pipes and making up new joints. It operates like a gland on a stuffing box, the method of operation being shown in the illustrations. The clamp consists of 3 parts, the first being a rigid clamp held firmly to the pipe by set screws, the second a loose clamp which screws against the packing, and the third a loose clamp holding the packing and follower ring. This third clamp bears against the fitting, as shown in the cross sectional view, and carries beneath it a ring of soft packing. Behind this packing comes a follower ring to force the packing forward, behind that the loose forcing clamp, and then the rigid clamp which fastens to the pipe.

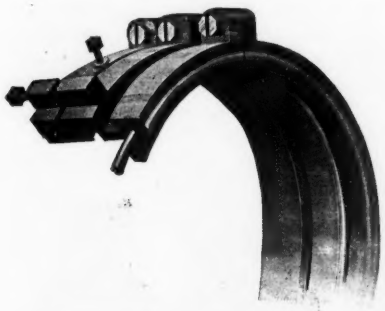
All rings are made in halves bolted together so that they may be applied around the pipe. The rings are put



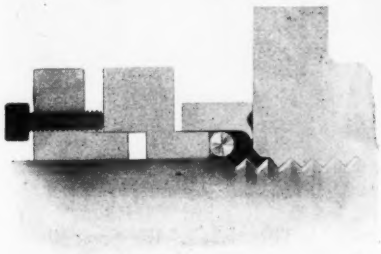
DART FLANGE UNION WITH INSERTED BEARING FACES

in place, the rigid clamp made fast to the pipe and the set screws are then forced in, driving the loose clamp, which acts as a gland, forward and forcing the follower ring against the packing in the stuffing box. This packing softens when it first comes in contact with the heat and is easily forced into the leaking joint, where it soon becomes semivulcanized, giving a permanent repair.

All parts of the clamp are made of brass, thus avoiding corrosion and making it possible to use the clamp a second time if there should be occasion to remove it and to remake the pipe line. The curved lip on the stuffing-box ring forces the packing strongly downward into the groove between the thread and fitting, thus preventing any possibility of steam or water working its way through.



PARTIAL VIEW OF THE HALF RINGS ASSEMBLED



SECTION OF CLAMP IN POSITION SHOWING THE GLAND ACTION

THE IDEAL CHAIN WRENCH

Kroeschell Bros. Co., Chicago, Ill.

THE IDEAL CHAIN WRENCH is a pipe wrench made with 2 kinds of biting surfaces in the jaws; it has the regular straight teeth for flat surfaces, such as pipe, rods, etc., and in addition to the straight biting surface it has a wide V-shaped biting surface of inclined teeth for round and square beaded fittings, etc. The V-shaped biting surface grips irregular surfaces of all kinds as readily as it grips pipe.

The jaws are tool steel, drop forged and saw tempered. A loose pin fastens the chain so that it is no trouble to put on a new, or reattach an old chain. Between the chain support and the jaws is a recess which enables the operator to take up all slack of the chain, and the automatic chain lock avoids all sticking.

STANDARD AND EXTRA HEAVY FLANGE FITTINGS

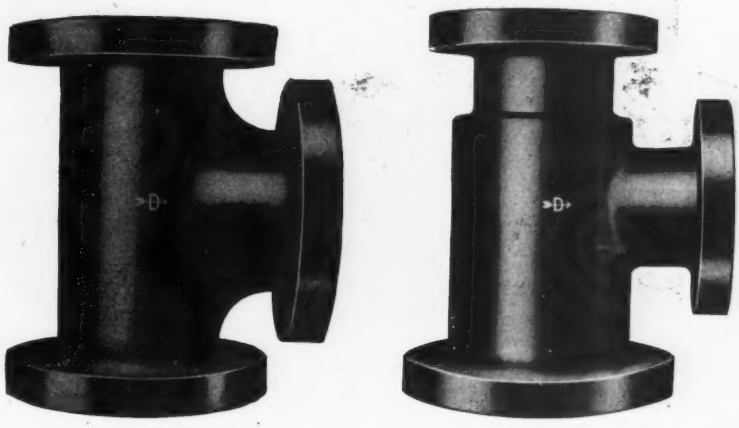
Direct Separator Co., Syracuse, N. Y.

THIS COMPANY MAKES a specialty of the manufacture of standard fittings, including blank flanges, screwed flanges, elbows for 90 or 45 deg., flanged tees of regular and reducing type, Y's and crosses. Samples of the work are shown, one of them being a standard flanged tee of equal outlet, run and inlet, and the other an extra heavy reducing flanged tee. Special attention is paid in the casting of these fittings, to get a mixture which will give freedom from gas pockets and shrink holes, and also to machine these fittings so that they will be accurate. They are made in gray cast iron and in semi-steel, to fit different conditions of pressure and temperature.

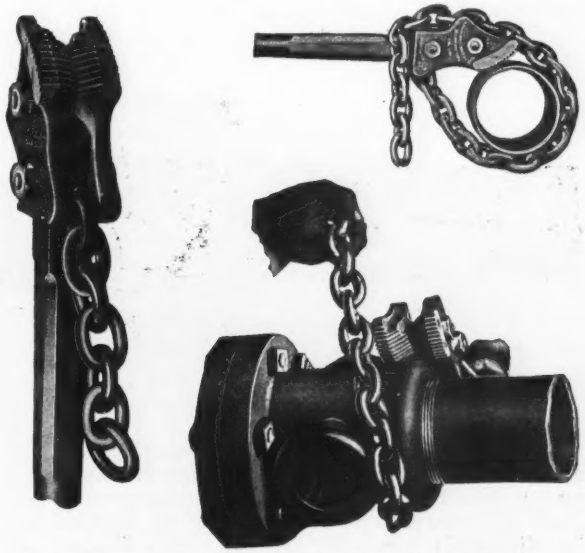
PIPE SPECIALTIES

National Tube Company, Pittsburgh, Pa.

IN THE KEWANEE UNION there are 3 solid parts and no inserted pieces. One section of the union is of iron, the other of brass, and the lock nut is of iron, so that the seat is a brass to iron ball joint, and the union threads are brass to iron which will not corrode and can be disconnected and reconnected an indefinite number of times without injury. These unions are made in either straight form as shown in the cross sectional view, or in eccentric pattern for reducing from a large pipe to a small one and keeping the bottom of the small pipe at the same level as the bottom of the large one, thus insuring perfect drainage. The unions are also made with male and female ends, or with both ends round, hexagon or octagon.



STANDARD FLANGED TEE AND EXTRA HEAVY REDUCING TEE

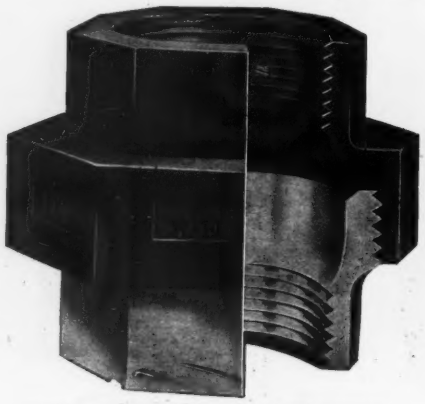


IDEAL CHAIN WRENCH AND METHOD OF USE ON PIPE AND ON FITTINGS

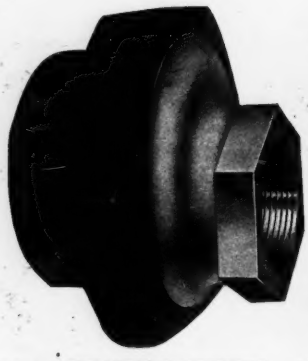
The union is also made up in the form of an ell with a union connection and with a tee with a union con-

nection. In either case the line connection end may be male or female connection. The advantage of these is evident, for in the case of the tee with union end it takes the place of a tee, a nipple, a union and another nipple.

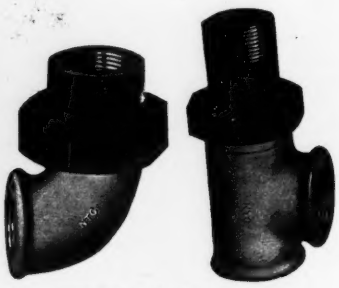
In the Kewanee flange union, malleable iron is used for the flanges and for all parts except the brass seat which is screwed into the socket end of the flange joint. The convex surface of the malleable fitting comes in contact with the concaved surface of the brass, permitting of a joint even when the 2 pipe ends are not in alinement.



OCTAGON PATTERN KEWANEE UNION



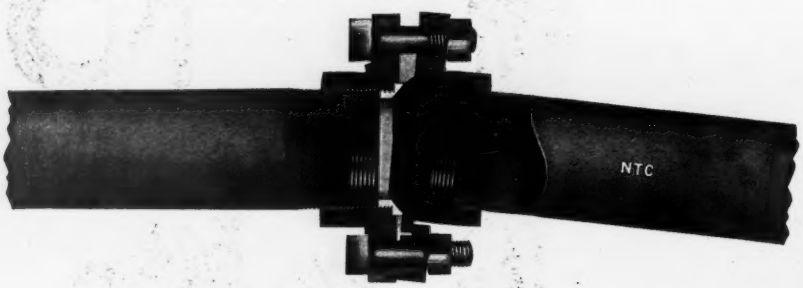
KEWANEE ECCENTRIC PATTERN UNION



UNION ELL AND TEE

For locations where space is scarce the Kewanee gate valves with union connections are convenient. These are of wedge gate pattern suitable for working pressures up to 175 lb., and are made to order only with one end fitted for an ordinary pipe connection and the other end arranged with a Kewanee union attachment.

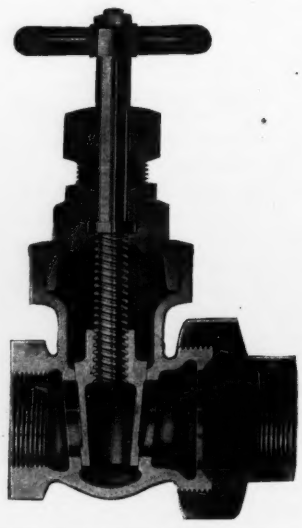
For supporting a line of piping the Western Expansion Pipe Hangers made by the National Tube Co. are convenient. They have side opening so that they can be applied after the line is put into position and have a swing connection at the top, allowing the pipe to come and go as much as necessary. By using these a line of pipe may be put up with temporary supports of any kind, and after it is properly lined up the hangers may be adjusted in permanent position. These hangers are made for pipes from ½ inch up to 8 inches, and the length of pipe which extends from the ring to the supporting button may be made of any length desired.



KEWANEE FLANGE UNION JOINT SHOWING ACTION WHEN PIPING IS OUT OF LINE

THE NEW PLASTIC-ELASTIC-METALLIC PACKING, called Wiebelin, recently put on the market by Everybody's Packing Co., Bourse Bldg., Philadelphia, has, as a consequence of solving some of the hardest problems, such as packing of acid pumps, air, ammonia and gas compressors, been adopted by many of the largest firms in the country and has proved its large utility. Another new packing placed on the market by this company, for places where unusually hard service is required, is the Diogenes sheet packing.

THE NATIONAL SOCIETY for the Promotion of Industrial Education, 20 West 44th St., New York City, has recently issued Bulletin No. 12, entitled Legislation Upon Industrial Education in the United States. The book is divided into 5 parts, the first of which is a reprint, with a few slight changes, of the first section of a pamphlet issued in 1909 by the American Association for Labor Legislation, prepared by Dr. Edward C. Elliott of the University of Wisconsin. This part of the book gives a general summary of the Legislation Relative to Industrial Education in Our Public Elementary and Secondary Schools. The remainder of the book was prepared especially for the National Society by C. A. Prosser, Deputy Commissioner of Education for the state of Massachusetts. After proposing a more definite nomenclature for the subject, Mr. Prosser has traced out the trend of legislation, giving an analysis of the legislation in Massachusetts, New York, Connecticut, Wisconsin and New Jersey. Mr. Prosser has brought to this work the advantage of a legal training, many years of practical school experience and an intimate professional knowledge of the field of industrial education, and his work has been done with a high degree of thoroughness, clearness and insight.

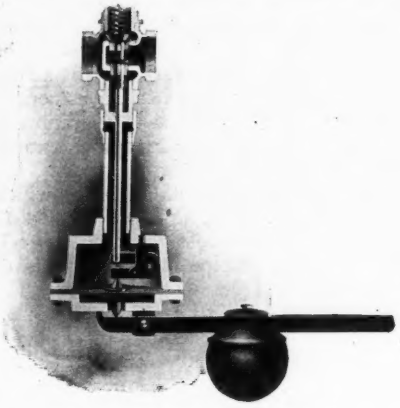


KEWANEE GATE VALVE WITH UNION END

KITTS REDUCING VALVE

Kitts Mfg. Co., Oswego, N. Y.

THIS VALVE OPERATES by means of the pressure from the low-pressure side of the pipe on a large diaphragm, this diaphragm being connected by means of a rod to the valves. These valves are double and balanced so that they operate freely. Pressure against the diaphragm is resisted by a lever arm and weight, while the closure of the valves is assisted by a light spring. When pressure on the outlet side of the valve, which is to the left in the illustration, rises, it forces down the diaphragm in the controlling chamber, raising the weight arm and weight, at the same time drawing down the valves and throttling the flow of steam. If pressure in the outlet falls, the reverse operation occurs.



THE KITTS REDUCING VALVE

PATTERSON SEPARATOR

Frank L. Patterson & Co., New York, N. Y.

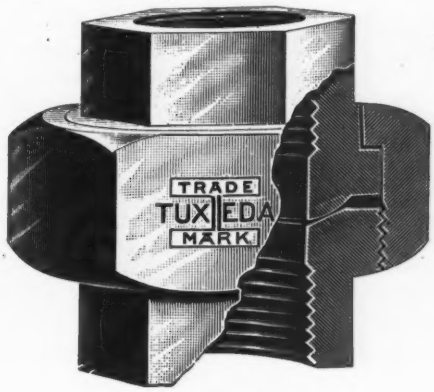
STEAM ENTERING THE right-hand end of this separator is caught by a curved baffle plate and given a reverse motion, passing through an opening in the main baffle and rising to the outlet. In its progress through the separator it expands greatly owing to the increased area of the separator and at the same time is caught and agitated by the side baffles, thus catching particles of moisture which may be entrained with the steam. Moisture drains to the bottom of the separator and is drawn away by a trap.

PATTERSON STEAM SEPARATOR

THE TUXEDA UNION

Franklin Williams, New York, N. Y.

IN THIS UNION a ball and socket joint is provided so that slight irregularity in pipe alinement will not produce a leaking joint. One half of the union is made of bronze, the other half of iron, and both halves are provided with hexagon necks so that they can be put on or taken off with an ordinary monkey wrench. The bevel seats do away with the necessity for packing and the extra heavy construction insures that a joint may be screwed up so that it will carry high pressure without injury to the union.

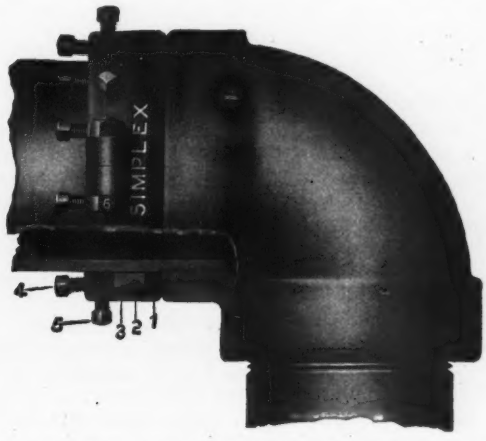


THE TUXEDO UNION

THE SIMPLEX PIPE CLAMP

Simplex Engineering Co., Philadelphia, Pa.

IN THIS CLAMP there are 3 parts, the outside ring which is made fast to the pipes by bolts which clamp to the pipe and by set screws in the outer edge; the inside ring which is loose and is forced forward by the set screws in the side of the outside ring; and the square packing ring which is forced by the loose ring forward against the joint, stopping the leak. The method of applying this joint is shown in the large illustration.



SIMPLEX PIPE CLAMP AND METHOD OF APPLYING

D'Olier Engineering Co. of Philadelphia has combined with B. B. Lathbury, formerly of Lathbury & Spackman, forming the Lathbury-D'Olier Co., which will continue the line of general and special engineering and contracting in the Morris Building, Philadelphia.

COMPRESSED AIR

USES, COMPRESSING APPARATUS AND AIR CIRCUITS

LIKE ALL OTHER METHODS of power transmission, that by means of compressed air is particularly adapted to certain classes of work, while for others it is inefficient and expensive. For instance, in a machine shop or steel construction work it has a field almost without competition. Here compressed air is used for operating drills, chisels, hammers, riveters, chippers, cleaners, sand blasts, calkers, small cranes, etc. While the efficiency of small tools is not high, the convenience with which the air can be piped and the absence of danger accompanying accidents makes compressed air for this purpose almost imperative where there is a great amount of work to be done.

In mines compressed air is used to operate rock drills, coal cutters, mine locomotives and other power driven machinery. It serves a double purpose in this work in that where a great deal of air is used, it helps to supply fresh air to the mine workers. There is also an advantage in using compressed air here in preference to steam for the exhaust is pure air and cool. The advantage which it presents over electricity in mines is that the danger of fire or explosion of gas, due to short circuits which frequently occur in electrical work is entirely eliminated and also the danger to the operator is likewise lessened.

TABLE I. POUNDS PRESSURE LOST BY FRICTION IN 1,000 FT. PIPE

CU. FT. FREE AIR PER MIN.	SIZE OF STANDARD PIPES, INCHES											
	1	1¼	1½	2	2½	3	3½	4	5	6	8	10
10	0.10											
20	2.6	0.60	0.2	0.06								
40	12.5	2.8	0.9	0.25	0.08							
60	—	6.5	2.0	0.58	0.16							
80	—	11.5	3.5	1.0	0.27	0.089						
100	—	—	5.5	1.55	0.41	0.155	0.05					
150	—	—	14.8	3.4	0.96	0.35	0.15	0.075				
200	—	—	26.0	6.	1.6	0.6	0.27	0.14				
250	—	—	—	9.5	2.7	1.0	0.44	0.21				
300	—	—	—	13.3	3.8	1.4	0.6	0.3	0.07			
350	—	—	—	—	5.25	2.	0.8	0.38	0.10			
400	—	—	—	—	6.75	2.6	1.05	0.55	0.14			
450	—	—	—	—	8.7	3.2	1.35	0.63	0.2			
500	—	—	—	—	10.6	4.0	1.75	0.83	0.25			
600	—	—	—	—	14.	5.6	2.4	1.16	0.28			
700	—	—	—	—	—	7.7	3.22	1.5	0.42			
800	—	—	—	—	—	10.2	4.2	2.1	0.65	0.28	0.08	
900	—	—	—	—	—	12.5	5.4	2.64	0.8	0.39	0.09	
1,000	—	—	—	—	—	14.5	6.6	3.2	1.0	0.5	0.10	
1,200	—	—	—	—	—	—	9.6	4.6	1.4	0.6	0.155	
1,400	—	—	—	—	—	—	13.0	6.0	1.7	0.75	0.215	
1,600	—	—	—	—	—	—	—	8.0	2.5	0.88	0.27	0.09
1,800	—	—	—	—	—	—	—	10.0	3.1	1.4	0.3	0.095
2,000	—	—	—	—	—	—	—	12.6	3.8	1.8	0.43	0.1
2,500	—	—	—	—	—	—	—	20.0	6.4	2.5	0.62	0.2
3,000	—	—	—	—	—	—	—	—	9.0	3.55	0.803	0.3
4,000	—	—	—	—	—	—	—	—	—	7.2	1.5	0.5
5,000	—	—	—	—	—	—	—	—	—	10.0	2.1	0.8
7,500	—	—	—	—	—	—	—	—	—	—	5.0	1.7
10,000	—	—	—	—	—	—	—	—	—	—	10.0	3.0

In gas engine plants, compressed air is used for starting the gas engine. Here the supply is stored from day to day in the receiver and no loss is occasioned by condensation, as would be the case with steam, and any unit may become independent of other power plants which would be impossible where electricity is used for this purpose supplied from an outside plant.

For long distance transmission, however, compressed air cannot compete with electricity, but has a great advantage over steam.

There has been, thus far, no formula developed for the loss of power in a compressed air line which can be considered accurate in predetermining the efficiency of a transmission of power by this means. This is due to the many changing physical conditions which present themselves. It may be stated in a general way that the loss of power is due to friction in the pipe which depends upon the size of pipe, the physical condition of its interior, the number and character of the bends in the pipe, the number and type of valves used, the velocity of air, the pressure of air and the length of pipe. It may also be stated here that the velocity is not uniform throughout the entire length of the pipe, owing to the fact that the pressure decreases with the length and consequently the volume increases, therefore the velocity is increased. With so many variables and conditions which cannot be predetermined, and are continually changing, only approximate calculations can be made to determine the loss in transmission prior to experimenting with the transmission line itself. Experiments, however, with plants that have been in operation, have given some valuable data which guide engineers in calculations for a compressed air transmission system.

An idea of the amount of the losses which occur in transmission of air can be had by reference to Table I, which gives the friction loss in pounds per sq. in. for each 1000 ft. length of pipe in various sizes discharging a given quantity of free air per minute. This table is based upon an inlet pressure of 75 lb. per sq. in., but approximate results may be had by using the values found in the table and multiplying by 1.2 for 60 lb. pressure and by 0.86 for 90 lb. pressure, and by 0.78 for 100 lb. pressure.

To transmit 200 cu. ft. of air 1000 ft. in a 1½ in. pipe, we lose 26 lb. pressure when the initial pressure is 75 lb.; this causes a loss of nearly 35 per cent. In transmitting air in a 2-in. pipe the same distance and initial pressure, we would lose 6 lb. by friction or a loss in percent of 8 which would be fairly good practice. If the pipe were extended to a length of 2,000 ft., the loss would be just twice this amount or 16 per cent.

A complete compressed air system for power purposes consists of a compressor, an intercooler, and aftercooler, a receiver, a transmission system, a reheater and air motors.

Power to Compress

IN order to get a clear conception of the power required to compress air, it is necessary to go somewhat into the theory and laws governing air compression.

The first law of gases, known as Boyle's law, has to do with the relation between pressure and volume of a perfect gas. Stated in words, it is: The pressure multiplied by the volume gives a constant quantity.

For example, 1 lb. of air at 60 deg. F. and atmospheric pressure occupies 13.09 cu. ft. In this case this constant quantity, in the above rule, is: 14.7 (which is the pressure of the atmosphere) multiplied by 13.09 giving 192.4. Under the conditions of this law, when the pressure changes the volume also changes so that the product remains the same. In other words, if the pressure was changed from 14.7 to 29.4, the volume would be 192.4 divided by 29.4 or 6.545.

Compression in accordance with this law is what is called isothermal and takes place without change in temperature of the gas during compression. It will be noted that this is an entirely theoretical condition and never exists in practical operation since by compressing the air friction within the gas itself causes heat to be developed.

The second law of gases is known as Charles' law and gives the relation between pressure, volume and temperature. This law states that, at constant pressure, the volume is proportional to the absolute temperature; that

is, the pressure multiplied by the volume equals absolute temperature multiplied by a constant quantity.

Again, the first law of thermodynamics states that heat converted into mechanical energy or mechanical energy converted into heat takes place without loss of energy, therefore the quantity of heat is exactly equivalent to the mechanical energy. Combining these laws we are able to get a theoretical value of the power required for compressing a giving quantity of air from any pressure to another pressure; likewise in the reverse order we are able to determine the amount of work which a given quantity of air at a certain pressure will do in expanding down to another pressure. This law of dynamics assumes, of course, that the gas at the higher pressure is under exactly the same conditions

TABLE II. POWER REQUIRED FOR COMPRESSING AIR FROM ATMOSPHERIC PRESSURE AT 70 DEG. F.

SINGLE STAGE COMPRESSION

GAGE PRESS.	ABSOLUTE PRESS.	NO. OF ATMOSPHERES	ISOTHERMAL COMPRESSION		ADIABATIC COMPRESSION			
			M.E.P.	H.P.	HP. PER CU. FT. OF FREE AIR	HP. + 15% FOR FRICTION	M.E.P.	M.E.P. + 15%
5	19.7	1.34	4.13	0.018	0.0197	0.0227	4.50	5.17
10	24.7	1.68	7.57	0.033	0.0362	0.0416	8.30	9.55
15	29.7	2.02	11.02	0.048	0.0504	0.0580	11.51	13.25
20	34.7	2.36	12.62	0.055	0.0628	0.0722	14.40	16.55
25	39.7	2.70	14.68	0.064	0.0742	0.0853	17.00	19.55
30	44.7	3.04	16.30	0.071	0.0845	0.0972	13.40	22.30
35	49.7	3.38	17.90	0.078	0.0944	0.1085	21.65	24.90
40	54.7	3.72	19.28	0.084	0.1030	0.1185	23.60	27.20
45	59.7	4.06	20.65	0.090	0.1112	0.1288	25.50	29.35
50	64.7	4.40	21.80	0.095	0.1195	0.1375	27.50	31.50
55	69.7	4.74	22.95	0.100	0.1268	0.1458	29.10	33.42
60	74.7	5.08	23.90	0.104	0.1339	0.1540	30.75	35.30
65	79.7	5.42	24.80	0.108	0.1408	0.1620	32.30	37.15
70	84.7	5.76	25.70	0.112	0.1472	0.169	33.80	38.90
75	89.7	6.10	26.62	0.116	0.1532	0.176	35.18	40.40
80	94.7	6.44	27.52	0.120	0.1590	0.183	36.55	42.00
85	99.7	6.78	28.21	0.123	0.1650	0.190	37.90	43.60
90	104.7	7.12	28.93	0.126	0.1705	0.196	39.10	44.92
95	109.7	7.46	29.60	0.129	0.1758	0.202	40.35	46.35
100	114.7	7.80	30.30	0.132	0.1812	0.208	41.65	47.85
105	119.7	8.14	31.00	0.135	0.1841	0.212	42.30	48.60
110	124.7	8.48	31.42	0.137	0.1908	0.219	43.75	50.35
115	129.7	8.82	32.1	0.140	0.1965	0.226	45.16	51.90
120	134.7	9.16	32.60	0.142	0.2008	0.231	46.00	52.88
125	139.7	9.50	33.2	0.145	0.2043	0.235	47.05	54.10
130	144.7	9.84	33.75	0.147	0.2085	0.240	47.80	55.15
135	149.7	10.18	34.3	0.149	0.2135	0.245	48.85	56.20
140	154.7	10.52	34.67	0.151	0.2176	0.249	49.90	57.35
145	159.7	10.86	34.11	0.153	0.2220	0.255	51.00	58.60
150	164.7	11.20	35.59	0.155	0.2255	0.259	51.70	59.50
155	169.7	11.54	35.98	0.157	0.2300	0.264	52.80	60.75
160	174.7	11.88	36.30	0.158	0.2321	0.267	53.40	61.45
165	179.7	12.22	36.75	0.160	0.2361	0.271	54.20	62.35
170	184.7	12.56	37.20	0.162	0.2408	0.277	55.25	63.50
175	189.7	12.90	37.65	0.164	0.2465	0.284	56.50	65.00
180	194.7	13.24	38.10	0.166	0.2480	0.286	57.00	65.65
185	199.7	13.58	38.50	0.168	0.2516	0.290	57.50	66.20
190	204.7	13.92	38.80	0.169	0.2550	0.293	58.25	67.00
195	209.7	14.26	39.80	0.171	0.2565	0.296	59.00	67.80
200	214.7	14.60	39.50	0.172	0.2600	0.299	59.75	68.75

during expansion that it was during the act of compression. This condition, however, is never attainable for heat losses always occur during compression and expansion.

Mechanical air compressors do not differ greatly from pumps, the air being drawn in during one stroke and compressed during the return stroke to the desired point at which time an exhaust valve is opened and the air delivered to a receiver or compressed air system. The pressure in the cylinder at any given instant during its travel on the compression stroke is the sum of 2 pressures. The first and greater is that due to the reduction of volume of air or isothermal and the second is the increase of pressure due to the increase in temperature. The sum of these 2 pressures at the various points gives values for a curve representing the pressure in an air cylinder during compression when no heat is being removed from the air volume, and this is known as adiabatic compression.

In actual practice it is noted that neither adiabatic nor isothermal compression takes place for there is always more or less radiation from the cylinder and it is impossible for practical purposes to remove all the heat as fast as it is developed in the air during the time it is being compressed. Therefore an indicator card will show the compression line of a compressor to be between the curves for adiabatic and isothermal compression. The losses due to compression in the cylinder, therefore, are principally those due to heating the air during compression as its temperature is reduced to that of the atmosphere when it is delivered to the air receiver; the energy therefore, which is stored up in the air is less than that necessary for compression by the difference between adiabatic and isothermal compression.

If by some mechanical process it is possible to maintain the temperature of the air during compression at that of the atmosphere, the energy of a given quantity of air in the receiver would be equal exactly to the energy required for compression. In modern, practice therefore it is common to employ water jacketed cylinders which remove a great share of the heat developed in the air during compression, and in 2-stage and 3-stage compressors the air is passed through what is known as an intercooler which reduces its temperature to that of the atmosphere before passing to the second and third cyinder for higher compression, thus, it will be seen, that the mechanical energy saved by this provision will be

TABLE III. POWER REQUIRED FOR COMPRESSING AIR FROM ATMOSPHERE AT 70 DEG. F.

TWO STAGE COMPRESSION

GAGE PRESS.	ABSOLUTE PRESS.	NO. OF ATMOSPHERES	ISOTHERMAL COMPRESSION		HP. PER CU. FT. OF FREE AIR	HP. + 15% FOR FRICTION	M.E.P.	M.E.P. + 15%
			M.E.P.	H.P.				
50	64.7	4.40	21.80	0.095	0.1063	0.1225	24.30	27.90
60	74.7	5.08	23.90	0.104	0.1184	0.1360	27.20	31.30
70	84.7	5.76	24.70	0.112	0.1286	0.1478	29.31	33.90
80	94.7	6.44	27.50	0.120	0.1372	0.1580	31.45	35.20
90	104.7	7.12	28.93	0.126	0.1462	0.1685	33.55	38.50
100	114.7	7.80	33.30	0.132	0.1542	0.1770	35.40	40.70
110	124.7	8.48	31.42	0.137	0.1615	0.1855	37.03	42.60
120	134.7	9.16	32.60	0.142	0.1681	0.1935	38.80	44.60
130	144.7	9.84	33.75	0.147	0.1740	0.2010	39.90	45.70
140	154.7	10.52	34.67	0.151	0.1810	0.2080	41.42	47.75
150	164.7	11.20	35.59	0.155	0.1865	0.2145	42.75	49.20
160	174.7	11.88	36.30	0.158	0.1912	0.2200	43.80	50.50
170	184.7	12.56	37.20	0.162	0.1968	0.2260	45.10	51.85
180	194.7	13.24	38.10	0.166	0.2015	0.2310	46.17	53.10
190	204.7	13.92	38.80	0.169	0.2068	0.2380	47.28	54.35
200	214.7	14.60	39.50	0.172	0.2110	0.2425	48.30	55.65
210	224.7	15.28	40.10	0.174	0.2155	0.2470	49.35	56.70
220	234.7	15.96	40.70	0.177	0.2196	0.2525	50.30	57.70
230	244.7	16.64	41.30	0.180	0.2240	0.2570	51.30	59.10
240	254.7	17.32	41.90	0.183	0.2280	0.2620	52.25	60.10
250	264.7	18.00	42.70	0.186	0.2315	0.2660	53.10	61.15
260	274.7	18.68	43.00	0.188	0.2350	0.2700	53.85	62.05
270	284.7	19.36	43.50	0.190	0.2385	0.2740	54.60	62.90
280	294.7	20.04	44.00	0.192	0.2420	0.2780	55.50	63.85
290	304.7	20.72	44.50	0.194	0.2455	0.2820	56.20	64.75
300	314.7	21.40	45.30	0.197	0.2490	0.2860	57.10	65.70

nearly the difference between adiabatic and isothermal compression from atmospheric pressure to the pressure in the receiver.

The power required for compressing air is calculated in a similar manner to that employed for determining the horsepower of a steam engine. In other words, the horsepower required for compression is calculated from an indicator card and is equal to the mean effective pressure multiplied by the area of the cylinder, times the piston speed in feet per minute, divided by 33,000. Theoretically, however, this would be obtained by use of the following rule: Divide the final pressure by the initial pressure, both given in pounds per square inch, absolute; raise this quotient to the 0.2857th power and subtract 1; multiply the result thus obtained by 0.000,005,999 times the initial absolute pressure, times the volume of air in cubic feet at the initial pressure delivered per minute; the result will be the horsepower required for single-stage compression without a water jacket on the cylinder.

Table II has been calculated by the use of this rule to show the horsepower required for the compression in single-stage compressors. In a similar manner table III has been calculated for 2-stage compression giving the horsepower required when the air is cooled down to atmospheric temperature between stages.

Air Compressor

BEFORE taking up in detail the construction and classification of air compressors, an analysis of an indicator card will aid in bringing out the points which should be observed in the design of air compressors to secure highest economy and efficiency, therefore in Fig. I we represent a theoretical card from an air compressor. The events which take place in the compression of air are practically the reverse of those in the steam engine,

The losses represented by this card are due to cylinder clearance, the suction pressure, the difference between actual compression and isothermal compression, and a real loss in compressing the air from intake pressure to atmospheric pressure.

Clearance in an air compressor cylinder is represented by the rectangle CRHI and since the expansion of the air in the clearance space is adiabatic owing to the

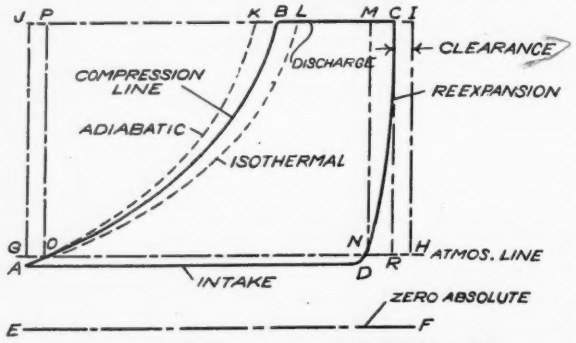


FIG. 1. THEORETICAL AIR COMPRESSOR CARD

fact that it takes place so rapidly that heat is not radiated, there is no loss of work due to the clearance in the cylinder. The loss, however, is that of volume, affecting the volumetric efficiency of the compressor.

The mechanical efficiency is equal to the indicated horsepower of the air cylinder divided by the indicated horsepower of the steam cylinder when a steam driven air compressor is employed. When the compressor is power driven the efficiency is found by dividing the indicated horsepower of the air cylinder by the brake horsepower of the driving wheel.

The volumetric efficiency is the ratio of volume of air actually compressed and discharged to the volume theoretically discharged in a given time. This is shown quite accurately on the card and may be taken as the ratio of the length NO to the length RG. While this is correct within certain limits there is another factor which comes in and affects the efficiency quite materially and this is due to the effect of temperature. In this regard it may be stated that cool air should be used for the intake and the intake valves should be as large as possible so as to increase the initial pressure of the air in the cylinder. It is possible by reducing the temperature of the air 10 deg. F. to increase the volumetric efficiency 2 per cent. The best method for keeping the temperature as low as possible is to provide an air duct of sufficient size to supply the compressor with air from out of doors at a low velocity through the intake pipe. The temperature within the engine room is usually several degrees above that outdoors and results obtained by the above provision are well worth the expense of installing such a system for the intake of air.

In compressors of the steam driven type some automatic arrangement is necessary in order to regulate the pressure in the receiver, keeping it uniform. This is accomplished in various ways, one of the most common, however, is to employ an air cylinder, which together with a flyball governor, operates to shut off the steam to the cylinder when the pressure in the receiver reaches the predetermined point and also at the same time to keep the speed of the engine to that allowable for best operation. Power driven machines are usually governed by an unloading device which allows the air to enter and discharge without compressing during the time when the pressure in the receiver is up to or above the desired point. This is done usually by holding the intake valves open. Air intake valves may be either of the poppet type or mechanically operated. When mechanically operated, the intake valves are actuated by eccentrics similar to those employed on Corliss engines.

Exhaust valves, however, have duties which make it expedient to use a poppet type for this purpose, owing to the fact that wire drawing is apt to occur and changing conditions of the atmosphere would cause the setting to be wrong. With the poppet type, as soon as the air reaches the predetermined point, the valves are opened and allow the air to go to the receiver without being diminished by wire drawing, or escaping back to the cylinder, thus increasing the clearance volume.

Motor driven compressors are governed by control systems which are operated by the pressure in the receiver causing current in the motor to be shut off when maximum pressure is reached and be started again when the air falls below the predetermined minimum. This arrangement puts the entire machine out of operation when not compressing air. Some system which automatically turns on current in small increments must be employed here as the compressor is started under load and the motor would be burned out were some provision of this sort not made.

Air compressors of the 2 or 3-stage type are nearly all provided with intercoolers which are in construction almost identical to feed water heaters, the current of air taking the place of the steam in the heater. The usual construction here is to employ a shell either of cast iron or of boiler iron according to the pressure employed, which is filled with circulating water tubes through which water at a low temperature is pumped. The interior of the shell being supplied wtih baffles which cause the air to pass several times across the pipes, thus to assume a temperature very close to that of the water. Provision is made in the shell for draining it of all water, leaving dry air for further compression.

Single-stage compressors are built for pressures up to 80 lb. but at this pressure and above, where large quantities of air are used the 2-stage compressor is the prevalent type.

Where pressures exceed 30 lb., it is the custom of manufacturers to water jacket the air cylinders, the method employed varying largely with the maker but in most cases, both cylinder and cylinder heads are jacketed. The arrangement of valves, however, limits or modifies this arrangement considerably.

The ratio between the diameters of cylinders of 2-stage compressors depends upon the initial and final pressures and the cylinders are so proportioned that approximately the same amount of work is done in each. Thus for sea level the ratio of diameters is 1.59 for 80 lb. final pressure; 1.67 for 100 lb.; 1.76 for 125 lb.; 1.83 for 150 lb.; 1.95 for 200 lb.; 2.06 for 250 lb.; and 2.15 for 300 lb. At an altitude of 5,000 ft. assuming an atmospheric pressure of 12.2 lb. the ratio of diameters becomes 1.66 for 80 lb.; 1.74 for 100 lb.; 1.83 for 125

lb.; 1.91 for 150 lb.; 2.04 for 200 lb.; 2.15 for 250 lb.; and 2.30 for 300 lb.

Aftercoolers

THE strains due to high temperature which are produced in compressed air pipe lines are apt to cause leakage at the joints and cracked pipes thus lowering efficiency of the line. As a precaution against high temperature, aftercoolers are employed which are placed between the compressor and receivers. These are, in all respects, similar to intercoolers but, of course, are subjected to higher pressures. Another duty of aftercoolers is to remove the moisture from the compressed air before it enters the receivers, a point which is frequently overlooked and may cause considerable trouble in the freezing up of air motors.

It will be realized that air pumped directly into the receiver is at a high temperature, being 484 deg. when compressed adiabatically to 100 lb. from atmosphere at 60 deg. F., and this high temperature extends along the pipe a distance proportional to the amount of air used, in that way causing expansion due to heat, which is not uniform throughout the entire length of the pipe and is continually changing.

If air could be used immediately when it is compressed with the temperature at a motor equal to that at the compressor, an aftercooler would be a wasteful piece of apparatus, but in common practice air becomes cooled down to the atmospheric temperature before it enters the air motor, thus, cooling without the provision of an aftercooler takes place all along the line causing strains, depositing moisture, and, owing to increased pressure due to this high temperature, the friction in the pipe is considerably greater than it would be at atmospheric temperature. Aftercooling is therefore an economy and is commonly employed in large compressing plants.

Receivers

FROM the aftercooler air is delivered to the receivers. These are cylindrical air tanks usually of boiler iron and may be either horizontal or vertical. They connect directly to the aftercooler with as straight and short a pipe as possible without ells or valves between them. The object of the receiver is to accumulate air and reduce pulsations of the compressor, its action being similar to that of the balance wheel on an engine. Where no aftercooler is employed, receivers are connected directly to the compressor and by the use of several, comparatively small in size, their radiating capacity is increased and the air may be cooled in this way. The discharge piping from the compressor should enter at the top and go down to within about 6 in. of the bottom of the tank. Outlet piping from the receiver should be on the side near the top and a drain should be provided at the bottom of the tank to carry off the precipitated moisture.

The receiver capacity cannot be too large, that is for best operation, its size being governed principally by space and initial cost. Each receiver should be provided with a safety valve, pressure gage and drain cocks. The best location is out of doors where the temperature is low and radiation of heat best secured. In this case the safety valves, drain cocks and gages should be placed inside the building with pipes running to the receiver, to prevent freezing up of these appliances.

Secondary receivers are essentially moisture traps and are placed at the low points of the pipe system where moisture is apt to collect. Connecting pipes are attached to the receiver from opposite sides or ends so as not to interfere with the flow of air. The secondary receivers should be placed in the line where the temperature has reached that of the atmosphere and should be provided with a drain, but a gage and relief valve are not necessary. Receivers should have careful attention and be drained out frequently and regularly while the plant is in operation.

Pipe Line

HAVING determined upon the size of pipe for allowable drop in pressure by means of Table I or by any other system, the features of the line are similar in nearly all respects to steam piping. Where an aftercooler is employed the strains are not so great but provision should be made for expansion and contraction of the pipe line due to changes in atmospheric temperature. Care should be exercised in the erection of a compressed air line to do away with tees, ells, valves, etc. as much as possible, the rules here being similar to those for steam.

The drop in pressure due to a globe valve is equivalent to the additional length of straight pipe as found by the following rule: Length of pipe equivalent in resistance to one globe valve equals 114 times the diameter squared, divided by the diameter plus 3.6.

The resistance of an elbow and tee is equal to 2/3 that of globe valves and in the calculation of the length of pipe in order to secure resistance to air flow, these lengths must be added to the actual length of the pipe line for each globe valve, elbow and tee. It is preferable in compressed air lines to employ gate valves instead of globe valves as their resistance is considerable less.

In the care of air pipe lines it should be remembered that leaks must not occur, when pressure will not remain over night as indicated by the pressure gage the pipe system can not be considered in first class condition. The pipes should be placed above ground where they can be cooled. When placed under ground radiation is not sufficient and the strains placed upon the pipe are greater than permissable, also proper inspection is impossible and leaks are hard to find. When, however, pipes must be placed beneath the ground the tunnel system is the one best employed where inspection can be made the entire length of the pipe line without a great deal of difficulty.

An idea as to the amount of loss taking place in the line may be had by stopping up all outlets and counting the number of strokes of the compressor which are required to maintain the required pressure upon the pipe system. For inspecting pipes a good plan is to paint the joints, valves, tees, etc. with soapy water and the leak will show up quickly by this method where the sound of escaping air may not be heard. Flange joints are preferable to screwed joints as the packing is done more easily and leaks are more easily prevented. Care should be taken in packing a joint to cut the packing so as not to interfere with the flow of air.

Expansion of the pipe line must be taken care of either by the use of expansion joints, packed slip joints, off setting the line every few hundred feet with wide angle bends or by some other means dictated by local conditions.

Every low place in the pipe system should be provided wtih the secondary receiver and drain cock. The importance of keeping the air free from moisture cannot be over emphasized as it will freeze up in the air motor and reduce its capacity if not removed.

Richards advises that the velocity of air in main pipe lines should not be more than 20 ft. per second and in branch lines the velocity should be still less for best operation.

For connecting up small motors, drills, chisels, etc. to the pipe system a flexible air hose is employed which is similar in all respects to steam hose. It is made strong

and flexible and may be either of rubber reinforced with wire or entirely of metal. Couplings of the hose should by such that they do not interfere with the flow of the air and strong enough to prevent all leaks.

Reheaters

WHERE air is used expansively in an air motor the temperature of the exhaust theoretically reaches 360 deg. below zero Fahrenheit. Temperature so low as this would cause great difficulty in lubrication of the motor cylinder and strains upon the apparatus which are severe. To overcome this difficulty reheaters are frequently employed which raise the temperature of the air to about that of the exhaust from the air compressor, before it enters the motor. By this means the temperature of the exhaust from the motor becomes in the neighborhood of atmospheric temperature and lubrication is thus made easy.

The method of heating the air is by means of internal combustion heaters, furnaces, gas jets or electricity. Internal combustion heaters are those in which the compressed air passes directly through the fuel bed and the entire products of combustion and air go to the air motor. This system is open to a great many objections in that soot is almost certain to stop up the air passages, also that the exhaust from the motors becomes impure and objectionable to the motor operator.

By far the most common type of reheater is that of furnaces provided with air passages strong enough to stand the pressure of the air, placed in the combustion chamber in such a way as to extract the great percentage of heat from the burned gas. The air is baffled through these passages and heated to the desired temperature then passes immediately to the air motor.

Gas jets are sometimes employed on small motors, these being placed directly in the air line just before the air enters the motor, the entire products of combustion going into the cylinder of the motor. The same objections may be offered to this as to internal combustion furnaces. Electric means have been employed for heating the air by placing a high resistance coil in the air line just before it enters the motor. This system is not, however, in general use. The economy of air reheaters may be illustrated by a study of the Charles' law that the pressure times the volume equals a constant times the absolute temperature. Here it will be noted that by increasing the temperature we have an effect similar to increasing the pressure. While this effect could be secured by a booster at this point this method is more expensive and by raising the temperature the advantage of high exhaust temperature is secured and less difficulty with lubricating the motor is experienced so that the reheating process is preferable to boosting the pressure.

Air Motors

THERE is little difference between steam engines and air motors where the air is used expansively. The principal difference being in the packing and lubrication employed. There are, of course, details in design which require, for most economical operation, slightly different arrangements, but air and steam engines are frequently used interchangeable with excellent results.

The decrease in temperature due to the expansion of the air in the cylinder is just the reverse of the increase due to compression of the air, owing to intermolecular action or friction. Just as in compression, isothermal compression is ideal, so in expansion isothermal expansion would be ideal. This is not attainable either in compression or expansion of air. Boyle's law governing gas pressure relations applies only to perfect gases which have no friction between molecules.

By Charles' law, we find that the pressure in the cylinder follows an adiabatic curve, both in expansion and compression, and this law takes into account the total proportionate drop in temperature. This also is never fully attained due to the absorption of heat from the cylinder walls by the air volume. Calculations, however, on the capacity of air motors are usually based upon adiabatic expansion.

Indicator cards taken from air motors, run expansively, are similar to those taken from steam engines but show less mean effect pressure and follow the adiabatic curve more closely than does the steam card. It may be stated, however, that air is not used expansively in a great share of apparatus operated by compressed air such as small tools, drills, chisels, hammers, etc. In a case of this sort the indicator card is almost a rectangle, the object being in most cases to secure a heavy blow at the end of the stroke and this would be impossible where the air is used expansively.

ALLIS-CHALMERS AIR COMPRESSOR

Allis-Chalmers Co., Milwaukee, Wis.

FOR THE STEAM END of steam driven compressors, a heavy duty Corliss engine either simple or combined is used, as the conditions of service may require. Both steam and air ends of the compressor are operated with equal efficiency and the arrangement of inlet and discharge openings is such that the speed of the air through the ports is slow compared with the capacity of the compressor.

The inlet valves are located below the piston level and removed from the heat zone of the cylinder thus insuring the incoming air from rise of temperature during admission. The entire surface of the cylinder head is available for discharge valves and the inlet valve is just below the bottom of the cylinder. Owing to the arrangement of the discharge ports over the entire cylinder head, it is impossible to water jacket the heads, but the manufacturer considers that on account of the greater increased radiation surface of this type of head, water jacketing is unnecessary.

The Corliss valve, which is well suited for compressor inlet valves is employed as it affords a quick free opening and admits the air in an unbroken stream, while at the same time a proportionately small surface of the heated metal is exposed to incoming air. The discharge valves are of the plain single beat poppet type.

The inlet valves are driven by eccentrics from the main shaft and by means of a wrist plate mounted on a stand on the side of the cylinder, they are given a quick opening and closing, and a slow movement when the ports are covered and the valves under pressure. The inlet ports are of ample size, short and direct, and the air is guided into the cylinder by an easy curve thus reducing the friction and insuring the complete filling of the cylinder with as little loss in pressure and as nearly the outside temperature as possible.

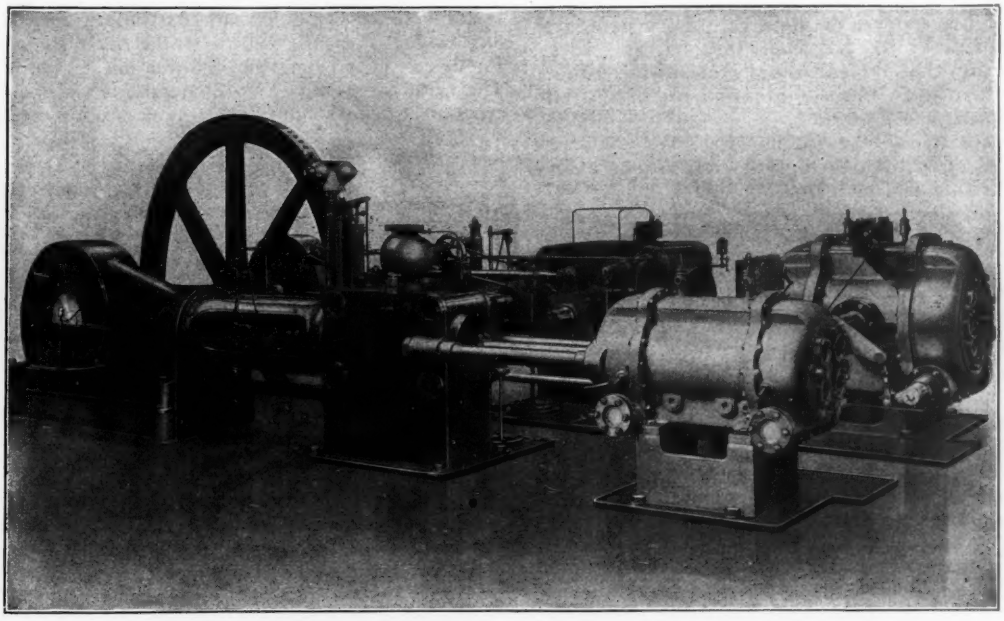
In steam driven compressors the steam and air cylinders are usually placed tandem, the proper arrangement in any case depending upon the style of compressor, type of air cylinder and conditions of operation.

The intercooler placed between the first and second stages of compression in the 2-stage compressor consists of a cast-iron or wrought steel shell, depending upon the size and pressure, fitted with cast-iron heads. The tube sheets are of thick steel plates and the tubes

of brass. The tubes are spaced so as to divide the air as it passes between and around them into thin sheets, and by means of baffle plates, the air is thoroughly mixed and brought into contact with all parts of the cooling surface. The air space is large so that the discharge of the air through the intercooler is slow.

In compressors driven by steam power, and where no power is taken from the steam end of the machine for other purposes requiring constant speed, regulation is accomplished by a specially designed air pressure regulator by means of which the speed of the air compressor is automatically varied according to the amount of air required thus maintaining constant air discharge pressure. This regulator receives its motion from a belt on the main shaft. A floating lever is attached to one end of the yoke on the regulator spindle, in the middle of the piston actuated by the air pressure and on the other end of the knock-off levers. As the air pressure rises the floating lever is forced down in the middle causing an earlier cut-off in the steam cylinders; at the same time the opposite end of the lever is moved to whatever position the indicator dictates. In this way the air pressure determines the speed of the regulator and consequently the speed of the engine.

The distinctive feature of this air compressor is the steam end which is a single direct acting cylinder, making use of an auxiliary plunger to carry the main slide valve which gives steam to the main piston. The plunger is reversed by means of 2 plain tappet valves and the entire mechanism thus consists of 4 stout pieces all working in direct line with the main piston. The operation is precisely the same as is used with the Cameron boiler feed pumps except that in the air compressor the air valves are placed above the cylinder with as short air ports as possible, the air valves being of the disk type.



ALLIS-CHALMERS CROSS-COMPOUND 2-STAGE STEAM DRIVEN AIR COMPRESSOR

CAMERON AIR PUMP OR COMPRESSOR

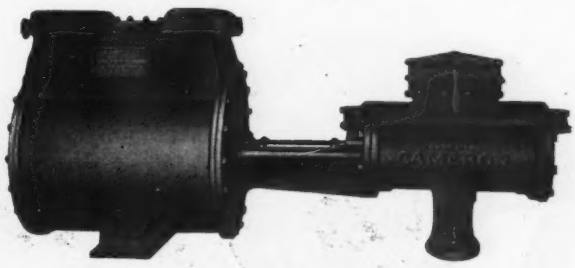
A. S. Cameron Steam Pump Works, New York, N. Y.

AIR PUMPS MANUFACTURED by the A. S. Cameron Steam Pump Works are direct acting, which, though not as economical in the use of steam as the crank and flywheel machine are much lower in first cost of installation and are suitable for delivering small quantities of air and are largely in demand for a great variety of purposes such as agitating oils, elevating acids requiring compression up to as high as 50 lb., and rendering a large steam end unnecessary. They are designed and constructed to give the best results under these operating conditions with the air cylinder water jacketed, built in capacities ranging from 10 to 500 cu. ft. of free air per minute.

CLAFLIN SEAMLESS BRAIDED HOSE

Chas. A. Claflin & Co., Boston, Mass.

IN THE TRANSMISSION of compressed air, as with steam, it frequently becomes necessary to have one or more flexible connections, either in the main piping system or at distributing points. Owing to the loss and delay consequent upon the failure of this device to perform its proper function, its consideration and selection is obviously of much importance.



CAMERON AIR PUMP OR COMPRESSOR

The Claflin Seamless Braided Hose and the Sure-Hold Hose Fittings, illustrated here, make an excellent combination for this purpose. The Claflin Hose is made of rubber and fabric so constructed that it is practically homogenous throughout. The rubber tube or lining is first made seamless and then completely covered with rubber cement, and while the cement is

still plastic, a seamless covering of fabric, consisting of closely twisted cotton yarn, is braided over it by a circular loom, after which it is again treated with rubber cement and one or more plies, depending upon strength desired, are braided on in like manner and then the whole is vulcanized by direct contact with live steam. Hose made in this way possesses 3 special characteristics: The first being great strength; for instance, the 1-in. size with 4 plies of fabric has resisted a hydraulic pressure of 1,000 lb. without bursting; second, its flexibility, the same 1-in. 4 play having been coiled within a 10-in. circle without kinking; third, its ability to give or yield through a pantographic movement of its diagonally braided structures, thus relieving the natural expansion of the rubber portions when hot. The combination of these 3 features begets serviceability.

The Sure-Hold Hose Fitting is a self-contained combination of a tubular nipple with the necessary

FIG. 1. THE CLAFLIN HOSE

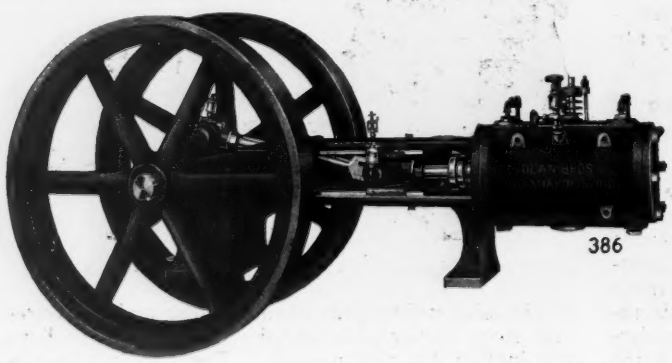
holding clamps hinged thereto and provided with a male or female union connection, as desired. The principle involved in effectually securing the hose is seen by reference to parts indicated with letters. A represents a circumferential enlargement forming an outwardly projecting convex rib, the purpose of which is to bulge that part of the hose immediately encircling the rib; B represents a concave recess formed on the inner surface of each clamp. When the clamps are brought together by means of bolts, these recesses not only surround, but straddle the bulge of the hose created by the rib, thus producing a sure hold, hence the name.

Hose and fittings are made in 6 sizes from ½ to 2 in. inclusive.

DEAN BROTHERS AIR COMPRESSOR

Dean Brothers Steam Pump Works, Indianapolis, Ind.

ONE TYPE OF SINGLE style, double acting air compressor made by this company as shown in the illustration, is operated by belt and is suitable for



DEAN BROTHERS SINGLE STYLE DOUBLE-ACTING AIR COMPRESSOR

working pressures up to 80 lb. The belt wheels are heavy and of ample diameter to reduce jerking motion and give a steady load on the belt or whatever power is used. The air cylinders are water jacketed and made with phosphor-bronze valves and seats, both inlet and outlet being of the poppet type. The valves are so located upon the cylinder as to reduce clearance to the least possible amount. With each compressor is provided an unloading device which automatically takes care of the demand for air.

DEMING TRIPLEX POWER AIR COMPRESSOR

The Deming Co., Salem, Ohio

SINGLE ACTING TRIPLEX air compressors have features similar to pumps of that description for handling water. The one shown in the illustration is made for delivering air against pressures not exceeding 80 lb. The main frame consists of 2 standards and includes the cross head guides and main crank shaft bearings, the

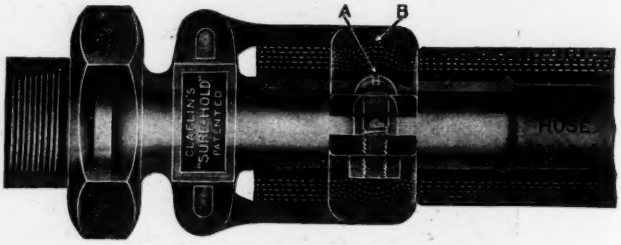


FIG. 2. SURE-HOLD HOSE FITTING

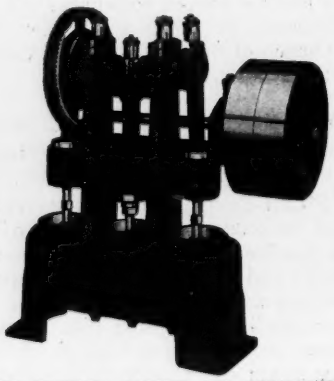
latter being lined with antifriction metal. The crank shaft is of open hearth steel casting in one piece, cranks being placed 120 degrees apart.

The cylinders are bored symetrically and are water jacketed, being equipped with steel valves which seat vertically upon bronze seats in such a position as to give the least clearance permissable.

DETROIT AIR COMPRESSOR CYLINDER LUBRICATOR

Detroit Lubricator Co., Detroit, Mich.

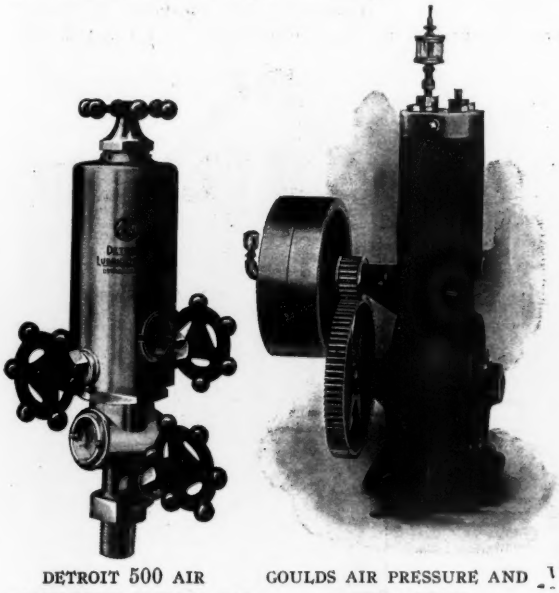
RECENTLY, A NEW STYLE of air compressor cylinder lubricator has been placed upon the market, known as Detroit 500. It has 3 valves and can be started and stopped without changing the feed and pressure adjustments. An oil valve controls the admission of oil to the valve which in turn regulates the rate of feeding, and a valve in the supporting arm prevents excessive back pressure which would cause the oil to spatter the sight feed glass. The oil supply



DEMING TRIPLEX POWER AIR COMPRESSOR

valve allows a permanent adjustment of the feed pressure valves because it alone controls the admission of oil to the feed, and therefore the other valves do

not have to be turned off to stop the feed and turned on to start it. After adjustment is once accurately made, it does not have to be changed. In starting up, the operator needs only to give the oil valve a few turns and the oil flows according to the adjustment which has been made permanently.



DETROIT 500 AIR COMPRESSOR LUBRICATOR

GOULDS AIR PRESSURE AND VACUUM PUMP

The lubricator is furnished in 2 types, one being with heavy tubular glass for pressure not exceeding 300 lb. and the other with extra heavy bullseye glass for pressure of 300 lb. or more.

GOULDS AIR PRESSURE AND VACUUM PUMP

The Goulds Manufacturing Co., Seneca Falls, N. Y.

BEING BUILT FOR 150 lb. pressure, continuous service, with a water jacketed cylinder, this pump is adapted for use where a small capacity is required, such as for starting gas engines, pneumatic tools, etc. The cylinder is symmetrical with a frame which catches all the oil from the piston. The connecting rod is provided with a wick which dips into the oil at the base and thoroughly lubricates the crank pin. The air valves are located at the top of the pump in the most accessible position and are made of hard steel in 1 piece. By this arrangement clearance is reduced to a minimum.

The pump is provided with a tight pulley having an extra heavy rim acting as a balance wheel and a regular loose pulley. This drive operates through a gear wheel upon the crank shaft whose rotation is kept uniform by means of the flywheel action of the belt wheel.

INGERSOLL-RAND AIR COMPRESSORS

Ingersoll-Rand Co., New York

THE ILLUSTRATION HEREWITH shows the Ingersoll-Rand Class "OC" duplex Corliss steam driven compressor designed for high-duty operation. This is one of the most recent types put out by this manufacturer, in a line which at present includes 20 standard types which are built in more than 1000 sizes and modifications. In the Class "OC" machine, where the steam cylinders are compounded the steam receiver is set below the floor and transversely. In compound air types the intercooler is transverse and above the cylinders. A special feature of this design is found in the main frames which are fully enclosed and which provide a flood lubrication system automatically supplying oil to all principal parts. Each frame is of the heavy-duty type, such as that employed in the most powerful rolling mill engines. It is supported on the foundation for its full length and is a one-piece construction.

The steam valve gear is of an improved Corliss liberating type with vacuum dash pots and double-ported steam and exhaust valves. The latches on the gear are of hardened steel with reversible and interchanging edges which can be used in succession as wear occurs. The air cylinders are of the full box construction, the box extending to the foundation and serving as a settling chamber for collecting mud or sediment which may be carried in the jacket water. The function of this chamber is to prevent the jacket space from filling up, thus impairing the efficiency of the jacket cooling. A feature of these cylinders is the absence of any air valves in the cylinder heads, which are completely jacketed. The Ingersoll-Rand Company considers the head jacket the most effective part of the jacket system because the air

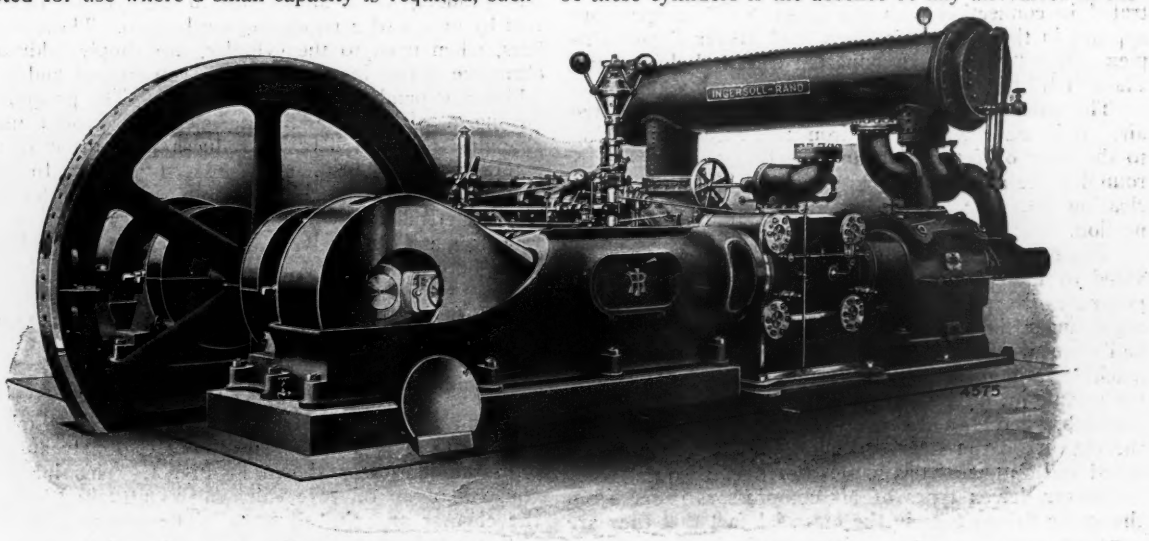


FIG. 1. INGERSOLL-RAND CLASS O C DUPLEX CORLISS STEAM DRIVEN COMPRESSOR

in the cylinder is in contact with the head throughout the entire stroke.

The air discharge passages are large and free, the low pressure discharge being more than one-half of the area of the low pressure cylinder. The discharge valves are arranged radially in the cylinder barrel and their large size provides a means of inspecting the interior of the cylinder.

Air inlet valves are of the Hurricane-Inlet type shown in the illustration. Air discharge valves are of the Cushioned Direct Lift type. Both of these types have the large area and the free but positive action which is so necessary in the economical compression of air. The intercooler in compound types is of liberal proportions, giving a large cooling area, ample receiver capacity and a velocity of air which is considered most economical. A means is provided for the removal of condensed moisture which might otherwise be carried over into the high pressure cylinder. The intercooler tubes can be

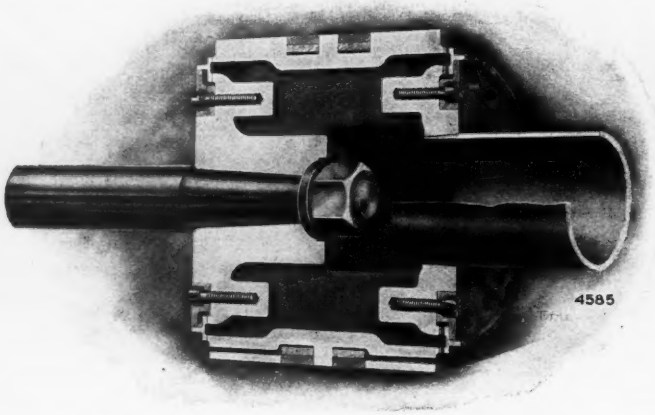


FIG. 2. HURRICANE INLET TYPE VALVE

removed bodily from the intercooler shell, and being entirely free at one end can expand and contract without causing leakage.

The same general type of construction as here illustrated in connection with the Class "OC" compressors appears in the company's Class "O" Meyer Steam Duplex, Class "PE" direct-connected electrical driven and Class "PB" heavy-duty power driven compressors.

The atmospheric intake is intended for handling free air. It is made with a cast-iron foot piece for bolting to the floor or foundation and the horizontal pipe surrounding the inlet tube is closed with a brass collar just clearing the tube, giving practically an air-tight connection.

The regulation of the Class "OC" compressor is provided by the combination of the ordinary flyball speed governor driven from the main shaft, with a pressure regulating cylinder connected to the receiver. The flyball element is a speed limiting device preventing the machine from going beyond a safe number of revolutions per minute in case of emergency. The pressure cylinder operates, when normal air pressure is exceeded, to change the cut-off on the steam cylinders and thus reduce the speed and output of the compressor.

Power driven types of air compressors differ from the steam driven type in the essential fact that they are constant speed machines. Some method of regulation therefore must be employed other than that of speed variation. One of the Ingersoll-Rand Company's regulators for power driven machines is illustrated, being the Imperial Unloader furnished on certain types. This is in effect a valve on the intake of the compressor operated by air pressure from the receiver. Under normal pressure the valve is fully opened. When pressure runs above normal the valve closes, wholly or in part, thus reducing the supply of air admitted and compressed, and reducing the capacity of the machine.

Another type of Ingersoll-Rand regulator for power driven machines, not here illustrated, is known as the

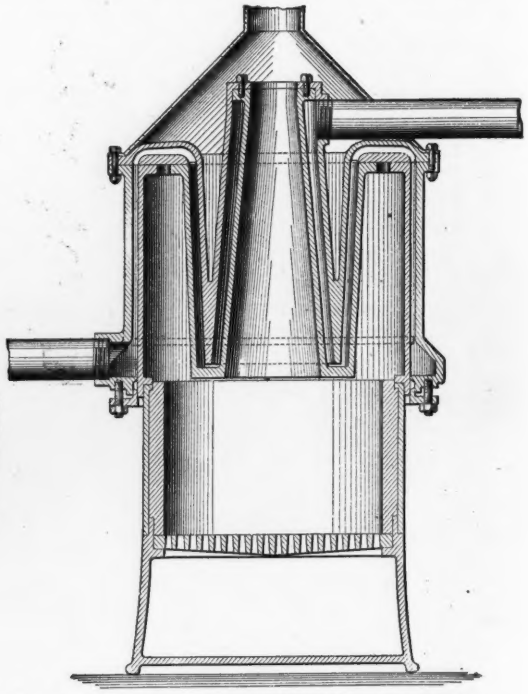


FIG. 3. EXTERIOR AND CROSS-SECTION OF INGERSOLL-RAND RE-HEATER

Clearance Controller. It consists of a number of auxiliary tanks or chambers connected to either end of the air cylinders, which are opened to the cylinder in rotation by means of a regulating mechanism. These chambers, when open to the cylinder, are simply additional clearance spaces into which air is compressed and from which it expands on the return stroke. The progressive cutting-in of these additional clearance spaces under changing pressure actually reduces the output of the compressor without material loss of power. In other words, power consumption is proportioned to the load. The Ingersoll-Rand Company also makes a line of air reheaters and air receivers, a cross section of the heater being here illustrated.

AUTOMATIC LUBRICATOR FOR PNEUMATIC TOOLS AND BOILER CLEANERS

Lagonda Mfg. Co., Springfield, O.

WEINLAND BOILER TUBE cleaners which use either steam or compressed air are regularly supplied with the lubricator shown in Fig. 1. This lubricator consists of an oil reservoir, and is attached between the cleaner and the air hose. The reservoir is filled with oil before the cleaner is inserted in the tube and by means of a screw the flow of oil can be regulated according to the needs. The oil flows from the reservoir into the air passage and is thoroughly mixed with the air before it enters the cleaner.

This type of lubricator has been in use for several years and has given uniform satisfaction, it sometimes happens, however, that when exceptionally hard scale is being bored out, the oil in the reservoir will be exhausted before a tube is finished and the cleaner will run hot before the operator notices it. In order to provide against this difficulty the manufacturer has brought out a new automatic lubricator shown in Fig. 2. This lubricator has the advantage that the cleaner does not have to be withdrawn from the tube in order to replenish the oil supply. Furthermore, the sight feed oil cup and suitable valves make it possible to

FIG. 1. REGULAR TYPE LUBRICATOR FOR TUBE CLEANER
FIG 2. METHOD OF FEEDING OIL DIRECTLY TO CLEANER THROUGH SMALL METAL HOSE

keep track exactly of the rate of the oil feed and to adjust the supply to the needs of the cleaner.

From Fig. 2 it will be seen that the Lagonda Lubricator can be attached to the air supply pipe in any convenient place, and consists of a sight-feed oil cup and 2 valves. As practically all air tools use flexible rubber hose it is inadvisable to mix the oil directly with the air and blow it through the entire hose, for oil causes rubber to deteriorate rapidly. This lubricator is provided with a separate flexible metal hose which conveys the oil directly to the tool and is placed inside of the rubber air hose. The location of the oil hose inside of the air hose is plainly shown in Fig. 2.

Referring again to Fig. 2, it is seen that the rate of oil feed can be regulated by the cock at the bottom of the oil cup, then by opening the valve, connected to the air supply, this oil is thoroughly mixed with a small portion of air and blown through the inner tube of the boiler tube cleaner or other pneumatic tool.

This lubricator can be placed on the wall or any other rigid object, and will therefore not be in the workman's way or subject to derangement by the vibrating tool.

MARSH AND AMERICAN AIR COMPRESSORS

American Steam Pump Co., Battle Creek, Mich.

STEAM CYLINDERS AND VALVE motion of the Marsh and American air compressors are of the Marsh type and the self-governing steam valve is admirably adapted to compression work, the piston load being always variable and of the cumulative order, in which the initial pressure is nothing, increasing to slightly above reservoir pressure at the end of the stroke. These conditions are met by the automatic governing feature of the admission valve, which operates to equalize the pressure in the steam cylinder to meet the constantly varying resistance of the air, and thereby combining economy in the use of steam.

In operation these compressors are almost noiseless. The piston has a smooth and easy motion and travels close up to the heads of the air cylinder, thus reducing the clearance to a minimum. The pistons are especially designed, combining strength, lightness and durability. The air valves and seats are of phos-

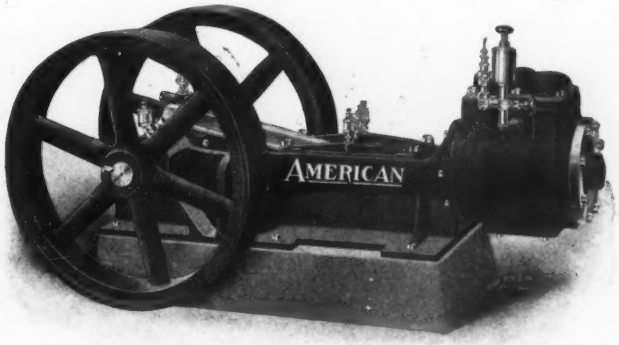


FIG. 2. AMERICAN POWER DRIVEN AIR COMPRESSOR

phor bronze, and are placed so near to the piston bore that valve port clearance is almost entirely eliminated. The air piston is provided with patent metallic expansion rings, which accurately fit the cylinder bore and require no attention. Cylinder valve and chest head caps, stuffing boxes, etc., are all polished bronze.

In the American line of power driven air compressors the cylinders are fitted with removable phos-

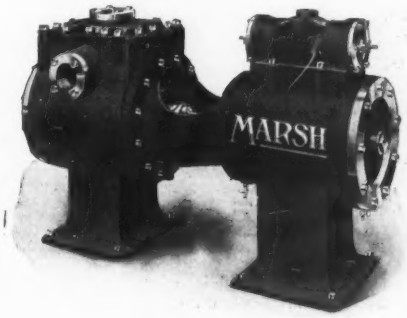


FIG. 1. MARSH STEAM DRIVEN AIR COMPRESSOR

phor bronze bushings, solid bronze piston rods, bronze valve seats, valve bolts and gland nuts. The frames are heavy and substantial castings of grey iron. Crosshead guides are planed. Bearings are of Babbitt metal. Connecting rods are of cast steel with adjustable bronze bushings at both ends. Cranks are open hearth steel castings. Gears are cast iron, machine cut.

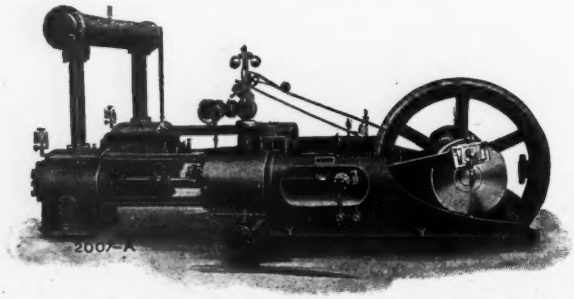
Marsh and American air compressors are made with capacities varying from 1 to 200 cu. ft. of free air per minute.

SMITH-VAILE AIR COMPRESSORS

The Platt Iron Works Co., Dayton, O.

SMITH-VAILE AIR COMPRESSORS are built in the following types: Steam actuated; straight line single stage; straight line 2 stage; duplex steam; duplex air; duplex steam, 2-stage air; cross compound steam, 2-stage air. In the belt actuated: Straight line single stage, straight line 2-stage, duplex single stage, duplex 2-stage. The steam machines may be fitted with plain slide valves, piston valves or Meyer or Corliss valve gear. In addition to the standard types made, the company builds numerous special machines.

All frames of the Smith-Vaile compressors are of a design affording strength and rigidity and have long



SMITH-VAILE CROSS-COMPOUND 2-STAGE AIR COMPRESSOR

bearings resting upon the foundations. They are all provided with bored guides and as the guides and end of the frames are machined at one setting the guides are in accurate alinement with the center line of the cylinders. The bearings in all cases form a part of the main frame. Compressors of 12-in. stroke and under have solid bearings of the diagonal design, lined with antifriction metal.

Provision is made for lubrication by means of sight feed oil cups placed on bearing caps, or the bearings may be provided with attachments which may be connected to central oiling system.

The air cylinders are made of hard close grained cast iron and are properly proportioned to the pressure with ample factor of safety after reboring. All cylinders are tested under a hydrostatic pressure in excess of the working pressure so that sound castings will be assured. Both inlet and outlet valves are located in cylinder body.

The cylinder walls and heads are provided with an efficient water jacket, flanged inlet and outlet openings and indicator openings. The air valves may be of either the poppet type or of the mechanically operated type, depending upon service conditions. The automatic or poppet valves are made of steel turned out of solid bar stock.

The valve and seat is self-contained, the seat being removable, and in cases of inspection or regrinding the valve and seat may readily be removed. All inlet valves are provided with safety stops so that should breakage occur the valves can not be drawn into the cylinders. Where the mechanically operated type is used they are of the semi rotative type operated by eccentric and rod from main shaft.

Both steam and air pistons are made of close grained iron of solid type with broad faces, being as light in weight as is consistent with good design and strength. They are accurately turned to a close fit in the cylinder and are fitted with cast-iron rings sprung into place.

On the straight line machines there are provided 2 flywheels of ample diameter and weight. On the belt driven type one of these flywheels is arranged as a belt wheel to accommodate a belt of suitable size.

On the duplex type but one flywheel is employed. The connecting rods are made of forged steel, circular in section. These connecting rods have either the marine type or the strap-end type of box depending upon the size of the machine, and are provided with adjustment for wear.

On all multi-stage machines there is provided an intercooler which is a necessity on this service. The intercooler is made of cast iron and the cooling surface consists of a number of brass tubes arranged in as compact form as is consistent with good practice. The tubes are inserted in the heads and provided with brass ferrules or glands which permit of expansion or contraction. The cooling water is passed through the tubes extracting the heat from the air which is passed around the tubes and in such manner as to divide the volumes into small currents and bring it into contact with as much of the surface as possible. The efficiency of the intercooler, other conditions being equal, is dependent upon the volume, area of cooled surface, and temperature of cooling water. The intercooler is provided with a pocket with suitable drain opening to retain any precipitated moisture, preventing it from entering the high pressure cylinder.

On belt driven machines an unleading governor may be used to advantage, and there is furnished with this type of machine an unloading governor, which automatically regulates the air flowing into the air cylinder. By preventing the atmosphere from entering the air cylinder the compressor can not do any work. This unloading governor is simply a balanced valve controlled by a pilot valve.

The governor is attached to the inlet of the compressor cylinder and the pilot valve is connected to the air receiver. There is a spring which may be regulated to allow the valve to unload at any desired pressure. When this desired pressure is reached the valve will gradually close, preventing inflow of air to the cylinder and with a slight fall in the receiver pressure the valve will gradually rise allowing the air to enter the cylinder, thereby giving the compressor its load again. This device works gradually, giving the compressor time to receive its load without shock. It is noiseless in operation and is close in regulation.

AFTER 10 YEARS OF GOVERNMENT service Allerton S. Cushman has withdrawn from his special work to start the Institute of Industrial Research at 804 Hibbs Bldg., Washington, D. C. Mr. Cushman and his associates will undertake the solving of industrial problems through laboratory and library research.

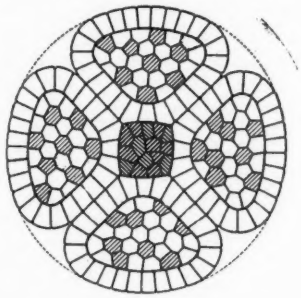
JOHN I. ROGERS has opened a New York office in the City Investing Building at 165 Broadway and will now use it as his main office. He is making a specialty of forging by the steam hammer, the drop hammer and the hydraulic press; of special rolling, such as railway tires and rolled wheels; of the use and manufacture of alloy steels, of machine shops and power plants and of general iron and steel works engineering. Mr. Rogers resigned from the Midvale Steel Company of Philadelphia about one year ago to take up professional practice and since that time has been engaged in consultation work and design along the above lines.

MANILA TRANSMISSION ROPE.

American Mfg. Co., New York, N. Y.

MANILA TRANSMISSION ROPE is made from the fibre of the Abaca plant, which grows only in the Phillipine Islands. The trunk of this plant, resembling the banana tree is closely enfolded by long leaves, and from these is procured the fibre so wonderfully suited to the requirements of rope. This fibre varies in length from 6 to 12 ft. and in some leaves attains a length of 18 ft. Its tensile strength is remarkable; official tests at Watertown, Mass., have proved it to be in excess of 50,000 lb. per square inch.

This great strength, however, is shown only when the fibres are subjected to a straightaway or longitudinal strain; transversely, owing to their cellular formation, the fibres are relatively weak. For this reason, in manufacturing transmission ropes, the greatest care is necessary to secure such proportion of twist, in both



1¼" "American" Transmission Rope Showing Lubricated and Cover Yarns

SECTION OF AMERICAN 4-STRAND ROPE

the yarns and the strands, as to render the rope least vulnerable to crosswise strains, and to the frictional wear and tear resulting from the constant rubbing and grinding of strands against each other while passing over the pulleys. Further, this correct proportion of twist is essential in order to assure the rope maintaining its proper form when put in service. To accomplish this, the fibres when making the yarns are first twisted to the right, next the yarns when making the strands are twisted to the left, and lastly, the strands are twisted together in a right-hand direction to form the finished rope.

For small drives, where the diameter of rope is less than ⅞ in., or where the rope is subject to much bending, the 3 strand rope gives excellent results, lending itself readily to abrupt turns.

For the large drives, the 4 and 6 strands are preferred; being more nearly circular, and of greater cross section, they secure a larger surface of contact in the groove.

A good transmission rope is the product of the most earnest and intelligent study of the principal points involved in rope-driving, the requisites necessary for such rope being:

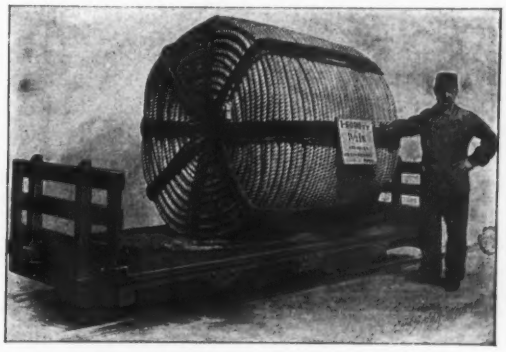
First, quality; to secure this, only the longest and strongest fibres should be used; no fibre less than 6 ft. in length should find its way into the yarns.

Second, preparation; this selected fibre before being spun into yarn, should be carefully "scutched," all tow, tangles, and harmful substances being removed, and the fibre thoroughly straightened.

Third, lubrication; transmission ropes wear out first on the inside, for, in bending about the sheaves, not only is frictional wear caused by the fibres rubbing one against the other, but the yarns which make up the strand slide upon each other and the strands in turn slide upon the core. To overcome this it is necessary to do more than merely provide large pulleys; the rope must be thoroughly and properly lubricated. The old style transmission rope was laid up in tallow, but tallow not only contains the injurious stearic acid, but as a lubricant soon dries out, leaving the inner fibre hard and brittle, and old ropes which externally appeared in good condition, when opened often disclosed the core and adjacent yarns reduced to a fine powder.

To overcome this drying effect of tallow upon the ropes, numerous so-called rope-dressings were put upon the market. The American Manufacturing Co., going deeper into the matter, hit upon a scientific method of preserving its ropes by treating several of the inner yarns of each strand, as well the core, in a bath of lubricant, the chief ingredients of which are graphite and a neutral oil. When the rope is put in service this lubricant thoroughly permeates all the fibres, thus overcoming internal wear, while sufficient comes to the surface to afford ample protection against injurious outside agencies. This lubricant, never leaves the rope, and as long as the strands and yarns remain together they are kept soft and pliable. Ropes so treated are self-lubricating, and need no external dressing whatsoever.

Fourth, arrangement of external yarns; as a further protection against external wear, the outer yarns



COIL OF ROPE IN A SINGLE LENGTH

of each strand are flattened, and arranged on edge around the inner yarns, like keystones of an arch, thus forming a thick covering for each strand. For this reason, after American Transmission Rope has been in service for years it may be taken up and respliced, enough of the outer yarns having survived with which to work.

Fifth, stretch; while to take up and resplice rope is a far simpler operation than to take up and cement belting, nevertheless the stretching of transmission ropes is a troublesome feature. To reduce the resplicing of ropes to a minimum, special machines have been constructed for the particular purpose of eliminating all save the initial stretch. With these machines, each yarn, strand, and finally the entire rope, is subjected to heavy tension during the whole course of construction.

Sixth, length; an additional feature of these machines enables ropes to be made 10,000 ft. in length without a splice. This is a decided advantage where long American drives are to be installed.

Through constant attention, and careful study of the features above, American Transmission Rope has been evolved.

ELECTRIC CIRCUITS

AS A MEANS OF transmitting great amounts of power long distances and adapting it to a diversity of industries electricity stands almost alone. In this article it is proposed to discuss electric circuits, both direct and alternating, and the various conditions and arrangements which affect the efficiency, economy, life and safety of the transmission circuit of isolated and factory plants where voltages do not exceed 3000.

Power may be transmitted economically by either direct or alternating current, the choice of the system depending upon the class of work to be performed, distances, allowable drop in voltages, changes in voltages necessary for different uses, type of circuit, whether it be exposed, enclosed or on poles, and its influence upon other apparatus, pipe lines telephone systems, etc.

There are 2 systems of distributing power by direct current electricity in common use. The most common is by means of a 2-wire circuit. Here the voltage at the motor is the same as that at the generator, except for the drop due to the heat of the transmission wire. This system is simple, the voltage is usually low and the calculation of the line drop, etc., are easily made. The 3-wire direct current system is employed where both motors and lights are run from the same generator, the voltage for motors being twice that employed on the lines and when the system is balanced and all 3 wires are of the same size the amount of copper used is 0.375 times that used on the 2-wire circuit. In many cases, however, the neutral wire is made half the size of the main wires, and in this case the amount of copper is 0.313 times that on 2-wire circuits for the same amount of power transmitted and per cent loss encountered on 2-wire circuits.

Allowable drop in any circuit should never exceed 10 per cent of the voltage at the generator. The drop in the line is equal to the current multiplied by the resistance in direct current systems. This does not change with the voltage employed but the per cent decreases as the voltage increases. To illustrate this by an example, suppose it is desired to carry 125 amperes, 1000 ft. to center of distribution having the delivery voltage of 220 and allowing 8 per cent drop. It is desired to find the size of wire necessary for these conditions.

If 220 is the delivered volts and 8 per cent drop is allowable, 220 would be 92 per cent of the generator voltage or 239.1 is the voltage at the generator. The drop in voltage is then 239.1—220=19.1 volts. Since the current is 125 amperes and the volts divided by the amperes equals the resistance in ohms, the resistance is 19.1÷125=0.1528 as the resistance of the circuit. Dividing this by 2 gives 0.0764 as the resistance of one wire 1000 ft. in length. From the wire tables we find that No. 00 wire has resistance of 0.0778 ohm per thousand feet and No. 000 wire has a resistance of 0.0617 ohm, it is better therefore to use the No. 000 wire as the drop will be less than 8 per cent. The exact drop is then found to be (0.0617×2×125=) 14.425, adding this to 220 the delivered volts gives 235.43 and the per cent drop will then be 15.43×100÷235.43=6.6 per cent drop which is within the requirements of the problem. By doubling the generator voltage the per cent drop is decreased one-half, although the voltage drop may remain the same, the power then delivered would also be twice as much with the same current in the circuit and it is evident therefore that with the same size wire and same per cent drop in voltage doubling the voltage will increase the power capacity of the circuit 4 times.

The above calculation is for a 2-wire direct current circuit. The 2 main wires of a 3-wire circuit are determined in the same way with double the voltage and half the current, the neutral wire varies from ½ to the full size of the main wires, depending upon the balanced condition of the system.

The resistance of a line wire for alternating current may, for most practical purposes, where the distance and voltage are moderate, be taken the same as for direct current. As a matter of fact, however, alternating current at the axis of the wire lags behind that near the surface of the wire and the resistance is therefore greater for alternating than for direct current.

In alternating current calculations, the factor corresponding to resistance in direct current is called impedence and is made up of 2 factors, these being ohmic resistance and reactance which is caused by inductance or capacity and varies with the class of service, size of wires, frequency of alternation, spacing and arrangement of wires in the transmission line. The numerical value of impedence is equal to the square root of the sum of the squares of the ohmic resistance and reactance. The 2 wires of an alternating current circuit form a condenser of considerable capacity and the combined influence of resistance, reactance and capacity of a circuit on the current and voltage lead to mathematical calculations beyond the scope of this article. For distances not extending 2 or 3 miles, the calculation of line drop on single phase circuits is the same for practical results as that employed for direct current circuits.

Two-phase circuits are considered as 2 single phase circuits, each transmitting half the power. In the calculation of 3-phase 3-wire circuits each wire is taken separately with the other 2 as return wires, the full load line current is used and the total drop in voltage is due to the drop in one wire. From these qualities, knowing the power factor of a circuit the approximate size of wire is calculated.

In the distribution of power by means of alternating current there are a number of systems which have certain advantages and disadvantages for particular classes of work. It may be stated, however, that the main reasons for developing these systems are the saving in the weight of copper necessary for the transmission of the current and the adaptability to different classes of work. To illustrate, taking the weight of copper required for single phase transmission on 2 wires as 100 the weight necessary for single phase 3-wire transmission for equal power on a balanced circuit would be 37.5; when the voltage between the main wires of the 3-wire system is the same as that of the 2-wire system the copper employed would weigh 150 per cent of that on the

2-wire system. Two phase, 4-wire circuits have 100 per cent of the weight of copper compared with that of single phase doing the same duty. Two-phase 3-wire circuits requires 72.9 per cent. Three-phase, 3-wire has 75 per cent of the weight of copper required on a single phase circuit for the same duty and the 3-phase, 4-wire system requires only 33.3 per cent of the weight of copper necessary for single phase transmission. In all these cases the same load and power factor are assumed.

Wire for Circuits

AT the present time hard drawn or annealed copper is almost invariably employed in the transmission of power. There are, however, cases where aluminum is employed for this purpose. The principal consideration here is the cost of installation and the relative convenience in handling the wires.

The tensions and sags given by these curves obviously hold true only at the time when the line is erected as the effect of temperature is not considered in the formula. Rise in temperature tends to increase sag and decrease the tension while a fall has the reverse effect. The elasticity of the wire, however, allows it to elongate somewhat under any tension which results from a fall in temperature. The accumulation of snow and sleet upon the wire adds considerable to its weight and consequently to the tension. In order to insure against accident it is necessary to adjust the tension of the wire when the line is erected so that under ordinary circumstances no future stress will be sufficient to exceed the elastic limit of the material in the wire.

The rule given by Lord Kelvin for the size of conductor for transmission of power by electricity is that the most economical cross section of the conductor

DROP IN VOLTAGE FOR EACH 1000 FT. TO CENTER OF DISTRIBUTION ON 2 WIRE CIRCUIT CARRYING DIFFERENT CURRENT

B.&S. GAGE OF WIRE	AMPERES																												
	10	12	14	16	18	20	25	30	35	40	45	50	60	70	80	90	100	125	150	175	200	225	250	275	300	325	350	375	400
	KILOWATTS DELIVERED AT 1000 VOLTS AND 90% POWER FACTOR																												
	9	1.08	12.6	14.4	16.2	18	22.5	27.	30.5	36	40.5	45.0	54.0	63.0	72.0	81.0	90.0	112.5	135.0	157.5	180.0	202.0	225.0	247.0	270.0	292.0	315.0	337.0	360.0
	KILOWATTS DELIVERED AT 1000 VOLTS AND 75% POWER FACTOR																												
	7.5	9.0	10.5	12.0	13.5	15.0	18.75	22.5	26.3	30.0	33.8	37.5	45.0	52.5	60.0	67.5	75.0	94.0	112.5	132	150	169	187.5	206.0	225.0	244.0	263.0	281.0	300.0
0000	0.981	1.18	1.37	1.57	1.76	1.96	2.45	2.94	3.43	3.92	4.41	4.90	5.88	6.86	7.85	8.83	9.81	12.3	14.7	17.2	19.6	22.1	24.5	27.0	29.4	31.8	34.3	36.7	39.2
000	1.23	1.48	1.72	1.97	2.22	2.46	3.08	3.69	4.30	4.92	5.54	6.15	7.38	8.62	9.85	11.1	12.3	15.4	18.5	21.5	24.6	27.7	30.8	33.9	36.9	40.0	43.1	46.1	49.2
00	1.56	1.87	2.18	2.50	2.81	3.12	3.9	4.68	5.46	6.24	7.02	7.80	9.37	10.9	12.5	14.0	15.6	19.5	23.4	27.3	31.2	35.1	39.0	42.9	46.8	50.7	54.6	58.5	62.4
0	1.97	2.36	2.76	3.15	3.55	3.94	4.92	5.91	6.90	7.88	8.87	9.85	11.8	13.8	15.8	17.7	19.7	24.6	29.6	34.5	39.4	44.3	49.2	54.2	59.1	64.0	69.0	74.0	78.8
1	2.48	2.98	3.47	3.97	4.47	4.96	6.20	7.45	8.68	9.92	11.2	12.4	14.9	17.3	19.8	22.3	24.8	31.0	37.2	43.4	49.6	55.8	62.0	68.2	74.5	80.6	86.8	93.0	99.2
2	3.12	3.74	4.37	4.99	5.62	6.24	7.80	9.37	10.9	12.47	14.0	15.58	18.7	21.8	24.9	28.1	31.2	39.0	46.8	54.6	62.4	70.2	78.0	85.8	93.6	101.0			
3	3.94	4.74	5.52	6.30	7.1	7.88	9.85	11.8	13.8	15.7	17.75	19.7	23.6	27.4	31.5	35.5	39.4	49.3	59.1	69.0	78.8	88.7	98.5						
4	4.97	5.97	6.96	7.95	8.95	9.95	12.4	14.9	17.4	19.9	22.4	24.8	29.8	34.8	39.8	44.7	49.7	62.1	74.5	87.0	99.5								
5	6.27	7.53	8.78	10.0	11.3	12.5	15.7	18.8	21.9	25.1	28.2	31.3	37.6	43.8	50.1	56.4	62.7	78.5	94.0	109.5									
6	7.91	9.5	11.05	12.6	14.2	15.8	19.8	23.7	27.7	31.6	35.6	39.5	47.4	55.3	63.2	71.1	79.1	98.8											
7	9.97	11.95	13.93	15.93	17.92	19.9	24.9	29.9	34.9	39.8	44.8	49.8	59.8	69.8	79.7	89.7	99.7												
8	12.57	15.1	17.6	20.1	22.6	25.1	31.4	37.7	44.0	50.3	56.5	62.8	75.4	88.0	100.5														
9	15.83	19.0	22.2	25.3	28.5	31.7	39.6	47.5	55.4	63.4	71.3	79.1	95.0																
10	20.0	24.0	28.0	32.0	36.0	40.0	50.0	60.0	70.0	80.0	90.0	100.																	
11	25.2	30.2	35.3	40.3	45.3	50.4	63.0	75.6	88.2	101.																			
12	31.8	38.2	44.5	50.9	57.2	63.6	79.5	95.5																					

It may be stated here by way of comparison that the specific gravity of copper is 8.93 per cent, that of aluminum 2.68; conductivity for equal area of copper is 100 and aluminum 63; the weight for equal conductivity of copper is 100, of aluminum, 48; area for equal conductivity of copper is 100, for aluminum, 160; diameter for equal conductivity of copper is 100, aluminum 126; the strength of hard drawn copper for equal area is 100 and aluminum 40. The gage of aluminum wire to be of equal conductivity with copper is almost exactly 2 sizes larger by B & S gage. While the conductivity of aluminum is only 63 per cent that of copper, aluminum wire of equal conductivity will have 48 per cent of the weight and from 110 to 160 per cent of the strength of annealed copper.

The accompanying tables show the relative strength, weight and resistance of annealed and hard drawn copper and aluminum.

It is of importance in erecting transmission lines to know the relation between the sag and tension in spans of various lengths and the accompanying chart has been worked out as a guide in this work. The curves are based upon the rule that the tension is equal to the span in feet squared, multiplied by the weight in pounds per foot of the wire divided by 10 times the deflection of the sag in feet. The weight per foot in this case is taken as ¼ lb., which is very nearly the weight of No. 1 B & S gage wire. The tensions and sags, however, for other weights per foot may be found by multiplying the values obtained from the curves by the weight per foot in question.

is that for which the annual interest of capital and outlay is equal to the annual cost of energy wasted. When this rule has been once sifted down it gives a current density in the wire of about 393 amperes per square inch. Prof. Forbes recommends 380 amperes per square inch as the most economical current density for transmission lines.

The drop in potential from the generator to motor ranges from 5 to 10 per cent and the latter should never be exceeded. It will be noted here that with generators of 90 per cent efficiency, motors of 90 per cent efficiency, transmission lines having a 5 per cent drop, the entire system will have an efficiency of 75 per cent. It may be stated that, at present, the approximate maximum efficiency in transmission by electricity is 80 per cent from the engine to the motor pulley.

Pole Circuits

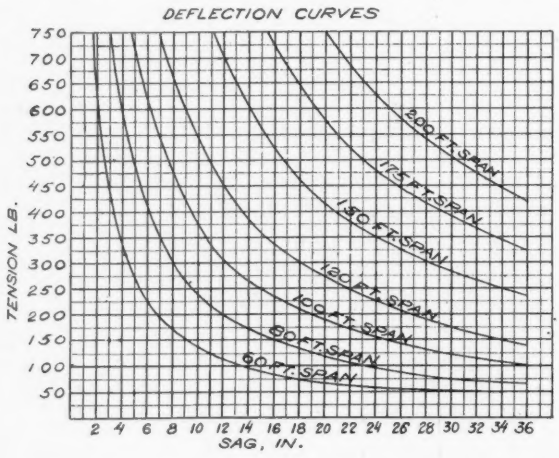
POLES used for supporting line wires may be of iron or wood. Iron poles are made of hollow wrought iron pipe with joints swaged or rusted together. For use as anchor poles iron lattice construction is frequently employed. The supporting insulators are mounted on iron brackets, the spacing being practically the same as for wood poles.

By far the most common material for poles of power circuits is wood, the kind depending largely upon the location where they are used. Chestnut makes an excellent pole for small sizes when it is sawed and hewn to serve the purpose. Large poles are made of pine, its particular advantage being that

it is straight and long but Southern pines and spruce are not so durable as cedar. This wood has a long life but the tree grows so crooked that for first class work cedar poles must be selected with great care. California redwood is recommended where it is available for use.

The action of fermentation set up by the sap in poles is apt to cause rapid deterioration which is augmented by decay caused by the action of the weather and the action of insects upon the material of the pole. Continual dampness does not decay the material, it is alternating wet and dry conditions which cause rapid deterioration.

The preservation of poles has been given considerable study and there are several processes employed



to prevent deterioration. Cyanizing is a process by means of which 3 per cent corrosive sublimate is allowed to saturate the pole.

As a rule, poles used for transmission purposes are from 35 to 60 ft. in length, though for some purposes they may be as long as 100 ft. Ordinarily 50 ft. poles or longer are put 1/10 of their length in the ground but under special conditions where the soil is soft this depth may be increased to ⅛ or 1/6 the total length. Where the ground is soft the pole is usually surrounded by grouting or Portland cement or the butt of the pole may be placed in a barrel and surrounded by sand or gravel which has been packed thoroughly around it.

Line poles are placed from 100 to 135 ft. apart and to prevent the wind pressure from throwing them over, every tenth pole should be guyed laterally with guy wires. The wire cable used for this purpose consists of several strands of galvanized iron or steel wire of No. 6 or 8 gage. The corner and terminal poles should be guyed in 2 directions, the guy wires running to an anchor in the ground at about 45 deg. from a point about 1/5 the length of the pole from the top or where the number of cross arms is considerable a Y shaped guy may be used with an extra strand running to the top of the pole.

Cross arms are made of yellow pine or oak and are usually in sizes from 3¼ by 4¼ to 4⅝ by 5¾ in. The length depends upon the number of wires carried, being 3 ft. for 2 wires, and 5 to 6 ft. for 4 wires, etc. The insulators are placed 4 to 6 in. from the ends of the cross arm, the space allowed in the middle being 24 to 30 in., and the space between wires varying from 12 to 18 in. It is usual in 3-phase transmission to place 1 wire at the top of the pole on a bracket and 2 wires on a single cross arm, thus making the distance between wires equal and the inductance upon each wire will therefore be the same. Their relative location is completely changed during the run between the ends of the line so as to cut down inductance.

The gains or flats are cut in the pole before it is erected and ordinarily are about 24 in. centers and the pole is usually cut wedge shaped at the top in order to keep the rain water from soaking down into the end of the pole.

Cross arms are fastened to the pole by 2 bolts or lag screws and braced by 2 strip iron braces. It is always best to put the cross arms alternately on opposite sides of the poles so that they can not be pulled off successively.

The pins employed for supporting the insulators may be of wood or iron bolts and are set squarely in the center and perpendicular to the arm, being securely fastened there by pins or nuts. For voltages not to exceed 2000 glass screw double petticoat insulators are usually employed, for voltages above this porcelain or special glass insulators must be used, the type and construction depending largely upon the size of the conductor and the fancy of the engineer.

Conduits and tunnels have become the rule in many factories and in case conductors are placed in these the cables must be insulated and where the possibility of being covered with water presents itself, lead covered cables must be employed. When the wires are placed in tunnels they are usually run on banks of arms on the side of the tunnel where they are easily reached by the wireman. Conduits of clay are made in cells of various numbers ranging from 1 or 2 up to any desired number. In these cases one cable is placed in each cell without insulating supports, other than the conduit itself which is made of insulating material, the conduits are run straight from one man-hole to another where connections are made or the cable is run in another direction.

It is common to employ iron conduits in the construction of buildings and these serve excellently for direct current wires. For alternating current, however, the inductance is apt to cause considerable loss of power by heating the conduit to an excessive degree. In this case it is necessary to run the 2 wires of the circuit in the same conduit, thus eliminating inductance effects upon the iron pipe. Moulding is used only for low voltage, principally for lights or small motors where current carried is small.

Transformers

THE advantage of employing alternating current for transmission purposes is due largely to the convenience in changing from one voltage to another with a nominal loss of power. This change is almost invariably made by the means of transformers, the ratio of transmission being anything which is desirable. Standard transformers, however, are made in ratios of 10 to 1 and 20 to 1 for voltages as high as 2200. These ratios can be varied somewhat by taps which lead from the transformer coils to the terminal blocks, changing the ratio 5, 10 or 15 per cent without materially altering its capacity, efficiency or regulation.

Connections for single phase operation are simple, the high tension leads are attached through fuse blocks directly to the transmission line and the low tension leads from the transformer connect directly to the service wires

of the system. The ratio of transformation is governed by the cross connections within the transformer case or in some makes by the method of connecting the low tension leads outside the case. These depend entirely upon the make of the transformer. Two phase circuits employ 2 single phase transformers in changing the line voltage to service voltage; the connections are identical with those used for single phase transformation.

In connecting transformers to 3-phase transmission circuits where 3 phase secondary circuits are desired, the connections may be made either star to star, star to delta, delta to delta, or by the use of 2 transformers a 3-phase transmission line may be converted into a 2-phase service line. The connection here being the 3-phase 2-phase. Another connection between 3-phase main line and 3-phase service line is the open delta. It is possible on 3-phase transmission lines to use single-phase transformers at any desired point, which will give a single-phase secondary circuit of any voltage which may be desired, but care must be taken under these circumstances to maintain a balanced circuit, thus not overloading any phase of the main circuit.

The location of a transformer should be as near as possible to the load which it is to carry, thus reducing the drop in the voltage from the transformer to the motor to the least possible amount. This is apt to run high as the voltage will be low. Transformers are frequently run in parallel between the main line and secondary, but this system is open to objections since where a circuit is heavily loaded, if the fuse on one transformer blows, the entire secondary system is apt to be put out of service for by removing one transformer all others are over loaded.

The best arrangement is to employ 1 transformer to feed its share of the load without having the secondary circuits connected. In this way should the load become excessive only a part of the secondary circuit is put out of commission.

Distributing transformers up to capacities of 50 kva. are commonly mounted upon the poles of the transmission line. The transformer case is then provided with lugs, by means of which the transformer is bolted to arm brackets which hang upon the cross arms of the pole in a convenient position so that the leads from the transformer are readily connected to the service and transmission lines. The leads from the transformer extend downward and are looped. The cover to the case is provided with a felt gasket which prevents moisture from seeping into the inside of the case, at the same time allowing free expansion of the oil which will take place when the transformer is loaded, due to increase in temperature.

For indoor use, the precautions to prevent water from entering the case are not necessary and the leads are usually taken out through the top of the case through insulating bushings, the arrangement of the leads depending largely upon the voltage of the system and the capacity of the transformer.

Man-hole transformers are placed in long cases and the leads are bushed and lead covered so as to prevent water from entering the case. These transformers are made thoroughly water tight, yet provided with sufficient air space to relieve for any expansion of the oil due to high temperature.

Protection of the Circuit

THE protection of a transformer circuit usually means the protection of the apparatus at both ends of the line against lightning and overload. There are, however, certain precautions which may be taken in the protection of the circuit, such as installation of pole type lightning arresters placed at the high points of the transmission line, which aid in dissipating the effect of lightning currents before they reach the ends of the line. Lightning arresters usually consist of a multiple gap arrangement in series with a high resistance shunted from the line side of a choke coil to the ground. The high surges of the lightning current in attempting to go through the choke coil are resisted, the potential between the terminal of the lightning arrester and the ground becomes sufficiently high to allow a discharge from gap to gap in the arrester, thus shunting the lightning currents to the ground through the multiple gaps and high resistance rather than through the power apparatus of the plant. The choke coil is placed directly in the line from the generator and consists of a spirally round coil, thus giving a coil of high inductance when the oscillations become enormous such as are experienced in lightning currents.

Other protections such as circuit breakers and fuse keep current density on the line below that which is injurious to the circuit.

CIRCUIT BREAKERS

THEIR SELECTION, ADJUSTMENT AND CARE

By D. S. Morgan

BEFORE selecting a circuit breaker, some consideration should be given to the points on which satisfactory service depends.

It should be borne in mind that the standard A. I. E. E. and National Board of Fire Underwriters' allowable temperature rise for this class of apparatus is 30 degrees Centigrade above the temperature of the surrounding atmosphere, and also that in actual service, the heating of the breaker does not depend alone upon the cross sectional area of the current carrying parts and the pressure on the contacts, but also on the temperature of the connections leading to and from the breaker.

A circuit breaker consists essentially of 3 things, (1) current carrying parts (2) operating mechanism (3) means of automatic tripping.

Main Contact Brush

THE main brush is preferably made up of leaf laminations, since with this design it can be so constructed that when the breaker is closed, an end-on contact under strong and uniform pressure is made between each lamination and the contact block. This end-on contact is obviously the best possible and of vital importance. An additional advantage of this construction is that the slight rubbing motion, which is given to the contact block by the brush laminations, when the breaker is being closed, keeps the contacts clear. Occasionally the main brush may need adjusting. A circuit breaker should be selected in which this is easily accomplished.

Secondary Contact

AS the circuit breaker opens, the main brush leaves contact first and transfers the circuit to the arcing tip and the carbon contacts. The arcing tip next breaks contact and opens any arc which may be due to the drop across the carbon contacts. Finally the circuit is opened and the arc ruptured on carbon blocks which are used for this purpose, because they are not readily destroyed by the action of the electric arc.

The construction of the secondary contacts is of great importance since they prevent damage to the main brush when the circuit is opened. The secondary contacts should be easily renewable at slight expense.

The carbon contacts should be made of specially selected carbon and held by clamping and sweating

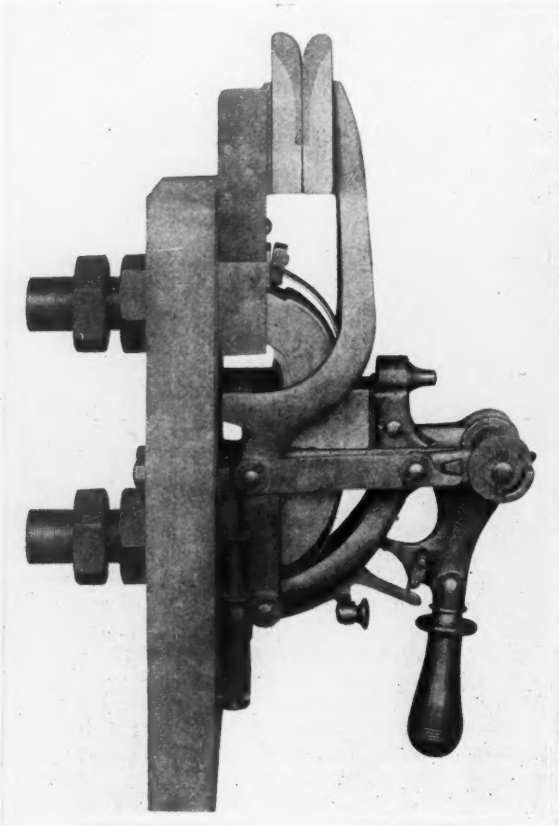


FIG. 1. HAND-OPERATED TYPE C, FORM K-2, D. C. GENERAL ELECTRIC CIRCUIT BREAKER

into the supporting jaws rather than by screws which require holes in the carbons and structurally weaken them. When screws are used for this purpose, they are subjected to more or less burning each time the arc is ruptured. They are thus soon put in such shape that it is difficult to remove them.

Mechanism

SINCE circuit breakers, especially those of large size, are nearly always located at the top of the switchboard it is necessary that they close easily; otherwise, the switchboard attendant would have difficulty in operating them.

The most effective method of doing this is by means of a toggle joint. With this arrangement the breakers can be closed with the minimum effort at the operating handle.

Also, with a toggle mechanism, the pressure on the tripping latch is so reduced that the minimum amount of power is required to release it, although this pressure is sufficient to make it impossible for the latch to trip out on account of vibration or jar.

To be reliable the mechanism should be so arranged that the circuit breaker must be either fully open or fully closed and can under no circumstances remain in an intermediate position. When the breaker is tripped its action should be quick and positive.

Attachments

SOMETIMES, changes in the operating conditions in a station make it necessary for a circuit breaker to take care of requirements differing from those which existed when it was installed. It is therefore of advantage to select a circuit breaker to which attachments for automatically tripping on low voltage, high voltage, reverse current, and reverse phase as

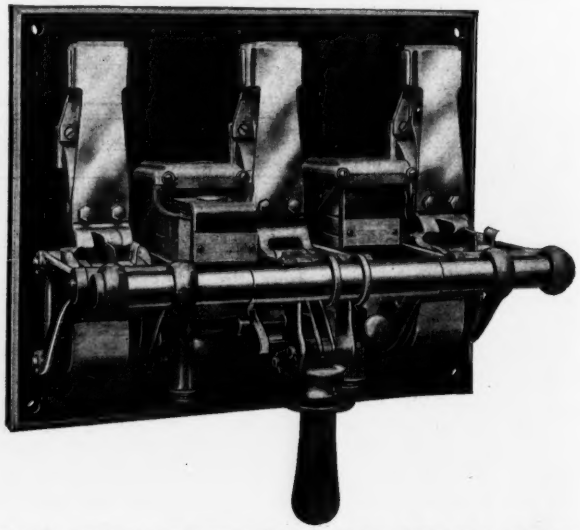


FIG. 2. GENERAL ELECTRIC 500 AMPERE, 250 VOLT, TRIPLE POLE A. C. CIRCUIT BREAKER PROVIDED WITH 2 OVERLOAD RELEASE COILS AND A NO VOLTAGE RELEASE COIL

well as auxiliary switches for bell ringing and signaling can be added without changing the breaker itself.

Means of Tripping

A CIRCUIT breaker is usually tripped by an electromagnet, the coil of which is in series with or across the line. When in series, the coil acts entirely according to the magnitude of the current and when connected across the line, the action depends on the voltage only. For tripping on overload and underload, the coil of the electro-magnet is in series with the line; on low voltage, the trip coil is connected across the line; on reverse current and reverse phase, relays are used acting in conjunction with the trip coil on the breaker.

Insulation

THERE should be adequate insulation between points of opposite polarity and between current carrying parts and ground. It is rarely advisable to insulate the current carrying parts from the operating mechanism of the breaker. If this seems necessary however, great care should be taken to see that this insulation can actually be depended upon because under such conditions, it is quite obvious that an insufficient safeguard is worse than none at all.

Adjustments

A WELL designed circuit breaker after being properly adjusted will give but little trouble. It should, however, be examined occasionally to see that the main secondary contacts are in good condi-

tion and make and break contact in their proper order.

An easy means for adjusting the main brush should be always provided. The brush should under no circumstances be filed, as this will spoil it in almost every case so that proper contact cannot be made afterward. It is well to remember that the tripping latches for holding the breaker closed are made of steel and are case hardened. Therefore they also should never be filed, for that would remove the hardened surface and cause the latches to wear rapidly thereafter.

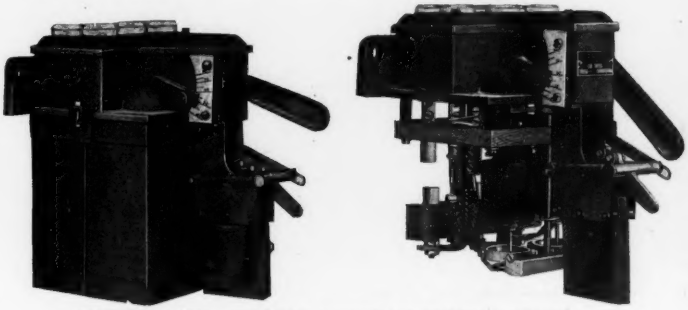
Care

A GOOD circuit breaker will in almost every case give satisfactory service for a long time. But that is no reason why it should be neglected or subjected to abuse. There is very little to say in this connection except to emphasize the important fact that, like any piece of apparatus electrical or otherwise, intelligent attention will increase its life and reliability.

WESTINGHOUSE CIRCUIT-BREAKERS

Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

TYPE H OIL circuit-breakers were designed for use on alternating current circuits, the voltages of which do not exceed 2500. The breaker is hand operated and can be furnished for mounting on the wall or on a switchboard panel. The maximum current



EXTERIOR AND INTERIOR VIEWS OF WESTINGHOUSE TYPE H OIL CIRCUIT BREAKER

carrying capacity is 300 amperes. This breaker is particularly adapted for use in industrial motor applications.

The breaker is compact in form, has all contact parts immersed in a tank of oil making a complete dust proof unit. It will open the circuit under conditions of heavy overload or short circuit without injury to the contacts. The contacts remain in the open position, due to gravity, a point of particular advantage, for the contacts will open the circuit in case the breaker should become disabled from any cause.

The full automatic overload mechanism of this circuit-breaker renders it impossible to hold the breakers in the closed position while a continued abnormal overload of short circuit condition exists on the line.

The overload release trip coils are suspended from the frame of the breaker, immersed in oil and connected in series with the line. The plungers of these coils are retarded in their movement by a device which imparts a time element to the action of the circuit-breaker.

This attachment introduces an element of time sufficient to permit the breaker to remain closed under a momentary overload or rush of current such as is incident to throwing the controller of an induction motor to running position. Should the overload, however, continue the plungers will trip the breaker and the speed with which they operate is inversely proportional to the rush of current.

An under voltage release attachment which will open the breaker whenever the voltage falls below a certain predetermined value, can be supplied. This device consists of a coil connected directly across the line for voltages not exceeding 600 and through voltage transformers for voltages in excess of 600. It is of particular advantage in automatically disconnecting the motor from the line at the time of temporary interruption to the power supply. Should the motor come to rest and still remain connected to the line, it will be subjected to full voltage upon the power being restored to the line.

The handle or lever used to operate the contacts is connected to them through a toggle mechanism.

The contacts are of the butt type, consisting of cylindrical brass rods, the lower ones being backed up

ALLIS-CHALMERS TRANSFORMER

by individual spiral springs which take up any wear and prevent any possible failure due to eating away of the contacts by arcing.

The operating mechanism is suspended from an iron frame to which the heavy welded steel oil tank is securely fastened. An adjusting mechanism is provided whereby the current at which the overload device will operate, may be regulated. The breaker may be set to trip at any point from 80 to 160 per cent of the normal current.

ALLIS-CHALMERS TRANSFORMER

Allis-Chalmers Co., Milwaukee, Wis.

IN THESE TRANSFORMERS the coils are wound on the 2 sides of a rectangular iron core, the secondary being placed next to the iron. The primary and secondary coils are divided so as to reduce magnetic leakage and secure close regulation. The coils are impregnated with insulating compound after they

have been thoroughly dried out and evaporated. The insulation between coil and core, also between primary and secondary is prepared from fuller board and mica which are unaffected by oil. This insulation is approximately symmetrical and has no sharp points liable to break down.

To maintain the coil free from hot spots the coils are made thin and designed so that the circulation of oil will carry off the heat from all parts and in no case is the copper more than 1 in. from the oil. Terminals connected to porcelain terminal blocks, allow the coils to be connected in parallel for 1050 or in series for 2100 volts. Changes in secondary connections are made by joining up the leads on the secondary mains so as to give the required series or parallel combination. Both primary and secondary leads are of flexible rubber covered cable treated so that it

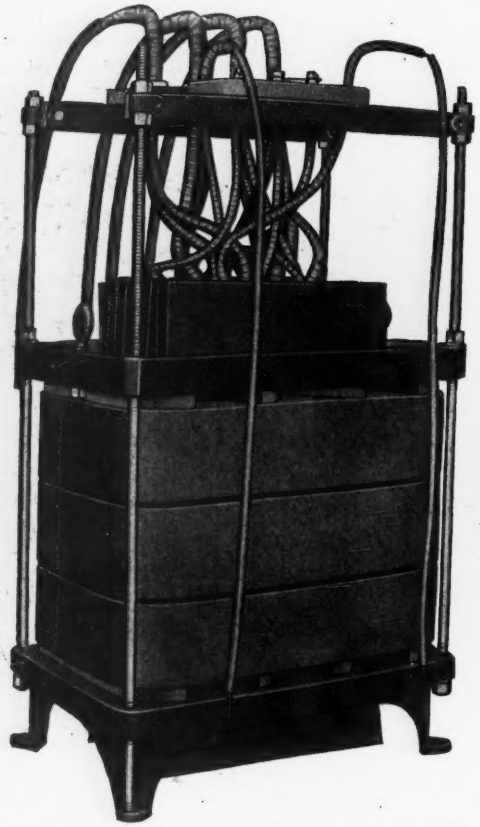


FIG. 1. FT. WAYNE TYPE A TRANSFORMER OUT OF ITS CASE

will not soften in oil. They pass into the case through porcelain bushings into which they are securely cemented. Each transformer is furnished with hanger hooks for cross arm suspension with eye bolts or hook for convenience in mounting upon poles. They are designed to carry full load continuously with a temperature rise not to exceed 45 deg. C., thus avoiding deteriorization of insulating material and aging of iron.

FORT WAYNE TYPE A TRANSFORMERS

Fort Wayne Electric Works, Fort Wayne, Ind.

FOR GENERAL USE about a factory the Type A constant potential transformers embody a number of details in design which make them convenient to work with, both indoors or outdoors upon the poles.

The core consists of punchings of very thin silicon alloy steel laid one on another to make the proper thickness. The shape of the punching is such that 2 laid side by side form the cross section of the core. In assembling them, alternate pairs are reversed causing the joints in successive layers to overlap.

The magnetic circuit thus formed surrounds the coil, closely encircling both high and low voltage windings, and consists of 2 branches, one around the upper, and one around the lower limb of the coil. To suit as many conditions as possible without increasing the cost or making a special transformer, these transformers in all capacities are designed with multiple primary and secondary coils, each coil wound upon a form and insulated complete in one unit. The coils being vacuum treated give no chance for a vibrating wire to chafe the insulation, and thereby cause a short circuit within the coil.

This construction allows the use of either 1100 or 2200 volts for the primary coils, the coils being divided into 2 equal groups, each being provided with a 10 per cent tap. When these 2 groups are connected in series it is possible to tap out at 5 or 10 per cent of the total winding, giving 3 primary combinations with corresponding changes in the secondary voltage.

The principal object in bringing out taps from transformer coils is to make up for line loss or drop in voltage between the power house and the transformer. It will thus be possible to secure a secondary voltage at the end of a line of considerable length which is equal to that or near the power station, thus permitting the use of motors, lamps and so forth of equal voltage in any part of the factory.

In the shell type of construction close regulation from no load to full load and equal voltages on 3-wire unbalanced circuits are obtained. This uniform voltage insures long life and superior service for incandescent lamps on secondary circuits.

Convenience in working with transformers mounted upon poles or placed upon a platform between 2 poles should never be overlooked in the installation of transformers. All sizes of type A transformers are furnished with lugs cast on the box into which are fitted the heads of bolts on suspension hooks for pole use. The small sizes have single-arm, 2-branch hooks, while larger sizes take 2 single branch hooks. Sizes 30 kw. and above are furnished with corrugated iron cases equipped with suitable base for use on platform or floor.

For protecting the primary circuit of transformers under 40 kw. capacity, elliptical plug fuse blocks are employed. The block and plug are all porcelain, in the form shown in the illustration, being mounted on a cross arm on the pole and replacing an extra insulator.

The manner of bringing the leads to the terminal block from which they are lead through insulators to the outside of the case as shown in the illustration. The shape of the transformer case is designed to make it convenient to work with, also to protect the leads from rain water which is apt to be carried into the coils of the transformer. The 2 eye bolts serve the double purpose of holding the lid tight upon the case, also making a convenient hold for the rope which is used in drawing the transformer to the top of the pole.

Another convenience in the use of eye bolts for this purpose is the ease with which they can be removed by the use of a pair of pliers when they are mounted upon poles.

KUHLMAN THREE-PHASE TRANSFORMERS

Kuhlman Electric Co., Elkhart, Ind.

FOR 3-PHASE POWER service or for lighting from a 3-phase system, the 3-phase transformer has many advantages over any combination of single-phase units. For exclusive power use it simplifies connections, takes up less room, gives higher efficiency and calls for a smaller investment than 3 single-phase transformers aggregating the same capacity.

For lighting or mixed lighting and power load there is the added advantage of always having phases balanced. Three-phase transformers with properly designed magnetic circuits will maintain primary phase balanced regardless of the load upon the secondary. The Kuhlman 3-phase transformer has 3 separate and distinct magnetic circuits of exactly equal reluctance, interconnected as are the windings

INDOOR TYPE OF KUHLMAN 3-PHASE TRANSFORMER

of 3-phase motors or generators. With this type of core, perfect electrical balance at all points of load is secured.

This type of transformer is primarily a power transformer, and will in most cases be called upon to deliver its full rated capacity constantly while in operation at all. For this reason the standard design calls for core and copper losses to be nearly equal, resulting in maximum efficiency at the full load point, and gives maximum temporary over-load capacity.

Transformers from 5 to 50 kw. capacity and for voltages up to 6,600 are built for pole suspension, outdoor type, larger sizes or for higher voltages are designed for use in-doors. The terminals in the pole type are brought out through substantial porcelain bushings under the projecting top of the case, downward at a slight angle in such a manner as to prevent moisture from entering case, or a possible grounding of terminals to the case.

TYPE S DISTRIBUTING TRANSFORMERS

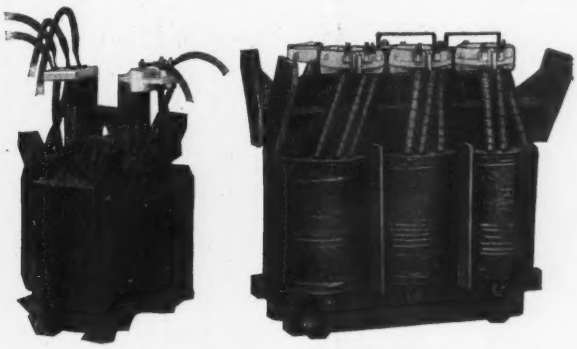
Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

THE CASES OF TYPE S transformers in sizes up to 50 kva., 60 cycles, are of cast iron, some of the larger sizes having corrugated sides to give increased heat radiating surface. Cases of transformers above 50 kva., 60 cycles, and above 25 kva., 25 cycles, have deeply corrugated sheet iron sides with top flange and bottom cast on. A felt gasket between the case and the cover and the sealed joints where the leads pass through porcelain bushings make the construction weather-proof. All cases are provided with lugs for handling and for mounting on hanger irons on poles.

The magnetic circuit is built up of thin laminations of sheet iron, so arranged as to give low core loss and low exciting current. The steel is carefully treated to prevent aging, and the cruciform arrangement presents a large oil cooled surface.

The coils are form wound and carefully insulated. Large ducts are provided for circulation of the oil, which prevents the development of hot spots in the windings. The insulation is designed for operation with grounded secondary, which puts the most severe strain on the insulation.

The terminals are brought to porcelain terminal blocks where connections are made to the transformer



WESTINGHOUSE TYPE S TRANSFORMER OUT OF CASE ASSEMBLED COILS AND CORE OF TYPE ST 3-PHASE TRANSFORMER

leads. The leads pass through porcelain insulators, in which they are sealed.

Type S transformers arranged particularly for manhole service are also furnished by the Westinghouse Co. These differ from the regular pole transformers only in the form of the case and its water-tight features. The cover joint is made water tight by means of a lead gasket and a large number of clamping bolts. Special, water-tight outlet bushings are also provided. Space is left between the oil level and the cover to allow for expansion of the oil when heated, and a safety relief valve is furnished, for relief in case of excessive air pressure.

For use in supplying power to 3-phase motors, it is often more desirable to use one 3-phase transformer than 3 single-phase transformers. The 3-phase transformer results in higher efficiency, less weight, smaller space and simplicity in wiring. For this purpose the Westinghouse Co. furnishes the Type ST 3-phase transformer. This follows the general design of the Type S, but differs in the form of the core. The core is built upon 3 legs of laminated steel, and on each leg the windings of one phase are placed. The windings are inter-connected and only 3 high tension leads and 3 low tension leads issue from the case.

CHAIN TRANSMISSION

THIS SYSTEM, in various forms, is used largely for the conveying of materials as well as for the transmission of power, and for certain special places it is coming into use for power transmission only. It is a positive method of driving, combining the definite speed ratio of gearing, with the flexibility of arrangement of belt drives. Progress in the use of chains has been rapid in the last few years, and from the crude malleable chains and cast sprockets first used to the hardened steel roller chains of accurate pitch and high tensile strength, and the milled sprockets now used, is a long step.

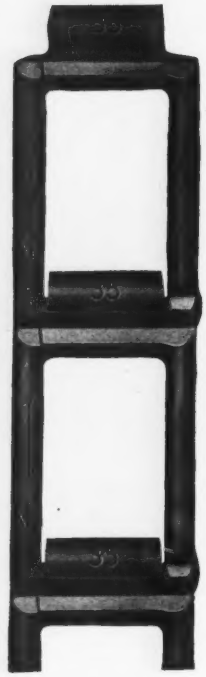
It is evident that with chain and sprocket there can be no slip so that the only loss in such transmission is from the internal friction of the chain itself and the friction of the chain on the sprocket. By using a roller chain or a rocking form and by the correct adaptation of sprocket to chain link the internal friction is largely reduced. Because of the positive connection between sprocket and chain a low tension on the chain is allowable thus reducing the friction in the bearings without slip. Also chains will obviously work with less injury in wet, oily, or extremely hot places than can any form of belted connection.

For high ratios of revolutions the positive action of the chain drive makes it available where a belt cannot go and also short centers can be used.

Perhaps the most common application up to the present time is the driving of machinery from motors where a considerable speed reduction with a short distance between motor and driven shafts is desirable. No exact data of speed limit for chain transmission has been established but many chains are running up to 2,000 ft. a minute and cases are frequent of over 1,200 ft. a minute, even when considerable power is being transmitted. Manufacturers of chains as a rule advise high speed and low tensile pull but 1,000 ft. is considered the usual limit for roller and 700 ft. for block chain. And for best efficiency sprockets should be made with not less than 14 teeth. In general, with increase of velocity the pitch of the chain may be increased or the chain tension may be increased. A longer pitch means a stronger chain per inch of width.

In planning a chain drive, allowance should be made for the fact that there is no possibility of slip and the chain must take whatever tension may come upon it by accidental overload, with no chance for relief. The chain itself and all parts of the drive should therefore be sufficiently strong to take care of any accidental strain. For best results the drive should be horizontal with driving side on the bottom, for long centers, and on top for short centers or very high speed, because for high speeds or short centers the chain will tend to cling to the sprocket.

In order to take care of wear on the chain the centers should be adjustable whenever possible, and if the drives are nearly vertical, adjustable centers are necessary, or for vertical drives where it is impossible to provide means of adjusting centers, an idler may be used on the slack side of the chain to insure correct meshing of the teeth and sprocket. This idler is usually a fibre wheel without sprocket teeth, and having flanges to keep it centered on the chain. For the ordinary form of malleable chain and sprocket the sizes, working strain, and power transmitted are shown in the accompanying Practical Table, in which it is considered that 0.7 of the working strain is available for the transmission of power, the remainder being expended in friction.



SIZE 35 DETACHABLE CHAIN

HORSEPOWER OF DETACHABLE CHAIN

NO.	APPROX. DIMENSIONS: LINKS IN 10 FT.	WIDTH IN IN.	WT. PER FT. LB.	BREAKING LOAD LB.	WORKING LOAD, LB.	FACTOR OF SAFETY: 6	7	8	10	12	14	16	20	30	45
						SPEED FT. PER MIN.: 100	200	300	400	500	600	700	800	900	1000
						HORSEPOWER TRANSMITTED									
10	280	—	—	150	45	0.07	0.13	0.17	0.18	0.19	0.19	0.19	0.18	0.13	0.10
21	191	—	2.9	250	80	0.12	0.21	0.28	0.30	0.31	0.32	0.33	0.30	0.22	0.16
23	185	—	2.4	200	65	0.10	0.17	0.22	0.24	0.25	0.25	0.26	0.24	0.18	0.13
25	133	3/4	2.4	500	75	0.25	0.43	0.57	0.60	0.63	0.65	0.65	0.56	0.45	0.33
31	132	—	3.2	500	100	0.25	0.43	0.57	0.60	0.63	0.65	0.65	0.56	0.45	0.33
32	104	15/16	3.5	750	150	0.37	0.64	0.85	0.90	1.94	0.97	0.97	0.90	0.68	0.50
33	86	15/16	3.3	1000	200	0.50	0.86	0.14	1.20	1.26	1.30	1.30	1.12	0.90	0.66
34	86	1 1/16	4.0	1100	225	0.55	0.94	1.25	1.32	1.38	1.43	1.43	1.23	0.99	0.73
35	74	1 3/16	4.1	1350	250	0.67	1.16	1.54	1.62	1.70	1.75	1.75	1.63	1.22	0.90
37	60	—	REST SAME AS NO. 33			—	—	—	—	—	—	—	—	—	—
42	88	1 1/4	5.3	1500	300	0.75	1.30	1.70	1.80	1.90	1.95	1.95	1.80	1.36	1.00
45	74	1 5/16	5.0	1600	350	0.80	1.38	1.81	1.93	2.02	2.07	2.07	1.81	1.45	1.06
44	80	1 5/16	5.3	1600	325	0.80	1.38	1.81	1.93	2.02	2.07	2.07	1.81	1.45	1.06
48	60	1 3/8	5.4	1500	375	—	—	SAME AS NO. 42				—	—	—	—
50	87	1 1/4	7.2	1400	350	0.71	1.21	1.59	1.70	1.77	1.82	1.86	1.70	1.28	0.94
51	104	1 1/8	7.4	1500	375	—	—	SAME AS NO 42				—	—	—	—
52	80	1 3/8	8.6	2000	500	1.00	1.73	2.26	2.40	2.54	2.60	2.60	2.26	1.81	1.33
55	74	1 5/16	7.1	1600	450	—	—	SAME AS NO. 45				—	—	—	—
57	52	1 3/4	8.9	2400	600	1.20	2.08	2.73	2.90	3.04	3.10	3.18	2.90	2.20	1.61

In using detachable malleable chain, care should be taken that for drives the hook end should run first, while on elevators or conveyors the bar end should run first. In installing these chains to insure good wearing life new chain and new sprocket wheels should be used with each other and when first starting up all slack should be taken out of the chain so that it will be held firmly to the wheels. The sprockets should be well oiled, and after running awhile to get limber and smooth the take up boxes can be somewhat slackened.

In the ordinary malleable chain, arrangements can be made for a quarter turn if the centers be sufficiently far apart, but with roller chain this is not ordinarily possible. When used for quarter turn the available strain should be figured as 0.5 the working strain. Low speeds are to be preferred as they permit of somewhat higher power transmitted by a given chain, and also of the use of smaller sprocket wheels. Figures for the tables given are taken largely from the data of the Jeffrey Mfg. Co., the Stephens-Adamson Co., and the Webster Mfg. Co.

While there has been considerable variation in the past practise in sprockets and chains, the effort is now to standardize both as to pitch of chain diameter of roller, width of chain and clearance on the sprocket. Dimensions of chain for roller and blocks form with rivets and side links are as shown in the accompanying Practical Table. In the matter of sprockets there should be side clearance and the teeth should be tapered at the ends. In one form made by the Diamond Chain & Mfg. Co. the top of the tooth is half the width between side links, the width of the tooth at the base is 1/64 in. less than the distance between side links when that distance is a quarter inch or less; 1/32 in. when the distance is 5/16 to 5/8 in.; 1/16 in. when the distance is 3/4 in.; and 3/32 in. when the space between side links is 1 in. or over.

Curvature for the taper of the end of the tooth begins at the pitch line. In case of a flanged sprocket, the chain must seat properly without the side bars striking the flanges. The distance from the pitch line to the shoulder should be, therefore, equal to about ½ the pitch of the chain.

Strength of Chains

THE tensile strength of block and roller chains runs from 1,250 up to 30,000 lb., but a factor of safety must be used of 10 to 40 according to speed and other conditions. If a low factor of safety is used, the chain is likely to elongate by wear until the pitch has increased so that the chain rides the sprockets, and then a wedging action takes place which will quickly wreck the chain. In order to have chains work correctly, fixed distances must be maintained between the sprockets, and the alinement of sprockets must at all times be perfect. The chain must be run neither too tight nor too loose as either condition produces excessive wear. The chain must be kept clean and should frequently be removed from the drive and immersed in melted grease and after 20 min. hung by one end to drain; when the chain is cool the outside should be wiped clean.

To give best results the chains should be covered in and run in oil the same as gears, and chains should always be so placed as to run in the same direction and the same side up.

In arranging for a roller chain drive, the length should be made a multiple of twice the pitch so that the union of the ends can be affected with an outside and inside link. Block chains may be ordered in multiples of the pitch, also link chain of the ordinary malleable form with detachable links. Block chain is made with standard 1 in. pitch, and in widths of 1/8, 3/16, 1/4, 5/16, 3/8, 1/2 and 5/8 in. The ultimate

STYLES OF JEFFREY DETACHABLE AND SPECIAL ROLLER TRANSMISSION

breaking strength ranges from 1,200 lbs. for the narrower width up to 1,700 lbs. for the 3/16, and 2,500 lb., for the 1/2-in.

DIAMOND CHAINS

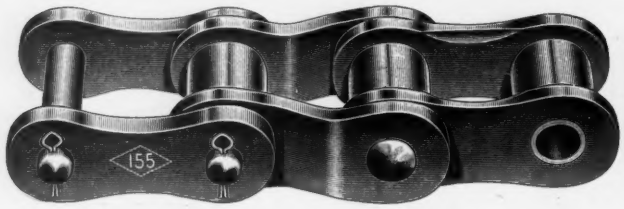
Diamond Chain and Mfg. Co., Indianapolis, Ind.

ALL STEELS USED in the manufacture of Diamond chains are of special analysis and are the best the mills of America can produce for the purpose.

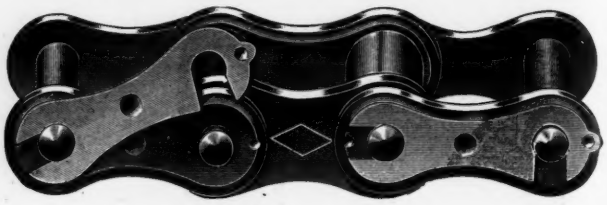
All holes in side bars of the larger sizes are accurately reamed to size and pitch—not punched. This reaming of holes of side bars and the assembling of bushings and rivets under heavy pressure, making them "a driving fit," results in rivets and bushings fitting the surface of the holes perfectly throughout the entire thickness of side bars—an impossible construction with simply a punched hole.

The construction of both the Diamond Solid Riveted and Detachable type of chain is shown in illustrations.

For the purpose of lengthening or shortening chain one link a special offset link is provided, while for use in making quick repair or adjustment a 3-link section, as shown in cut, is furnished.



DIAMOND OFFSET REPAIR LINKS

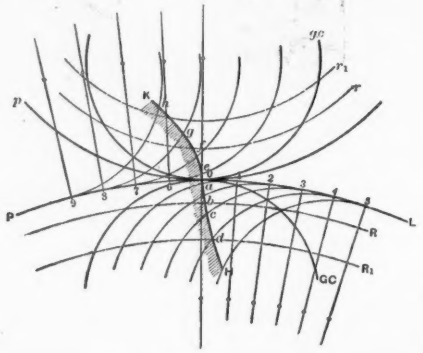


DIAMOND DETACHABLE CHAIN

This company also manufactures a full line of sprockets.

GEARING

AS MENTIONED IN the general discussion on the transmission problem, gears are used more in the distribution of power throughout a machine than in the transmission, but in certain classes of work, such as rolling mills, wire rope drive and connection of motors to pumps and machine tools, gears play an important part. They are used usually as a supplement to some other form of drive rather than as a complete system, the only place where any considerable power is transmitted by the gearing alone being between water wheel and generator in a hydraulic plant and between engine and rolls in a rolling mill. The particular advantage is the positive speed ratio secured and the particular problem is to get a form of tooth which will hold the same steady speed ratio that would be had by friction wheels rolling against each other.

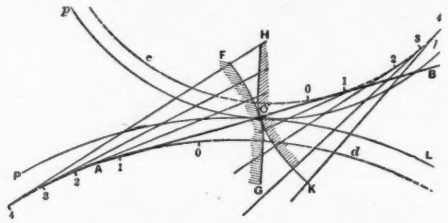


METHOD OF GENERATING CYCLOIDAL OUTLINES (KENT)

Investigation of possible forms of teeth has resulted in the choice of 2 which fulfill the required conditions, one known as the involute, the other as the cycloidal system of tooth outlines. If these are properly designed and used, the speeds of 2 gears working together will be inversely as the diameters, the same as would be the case if the equivalent cylinders rolled together. The diameters of these equivalent cylinders are known as the pitch diameters of the gears and the circles run about through the middle of the height of the tooth.

In the cycloidal system the tooth outline is generated by a point on a circle which rolls on the pitch circle as indicated in the illustration. To form the part of the tooth outside the pitch line the rolling circle travels on the outside of the pitch circle and to form the part of the tooth inside the pitch line the rolling circle travels on the inside of the pitch circle.

For teeth which are to work together the same rolling circle must be used and the most common form for interchangeable gears uses a circle which has half the diameter of the smallest gear of the series, usually one having 12 teeth. This gives a radial line for the part of the tooth inside the pitch circle, called the flank, on the smallest gear. A rolling circle larger than this produces an under-cut tooth which is weak; but if a pair of large gears are designed for transmission purposes and have no occasion to be interchangeable, frequently a larger rolling circle than that for interchangeable gears is desirable because the small rolling circle gives a tooth which flares wide at the base in large gears and produces, therefore, a considerable wedging action tending to force the gears apart. In the involute system the outline of the tooth outside the pitch circle is produced by a point on a cord unwound from the base circle, this base circle depending on the angle chosen for the system. It is found by drawing through the point of contact of the pitch cir-



FINDING THE INVOLUTE OUTLINE (KENT)

cles a line at an angle with the tangent to the pitch circles, for common practice this angle is taken as 15 deg. The base circle is then drawn tangent to this oblique line and the tooth outline is formed by a cord starting at the pitch point and unwinding from around the circumference of the base circle, as indicated in the illustration.

Each system has advantages of its own. The involute system in small gears produces a flatter top than the cycloidal, therefore more tendency to wedge the gears apart. The involute tooth below the base line is radial, hence has a weak base as compared with the cycloidal tooth. The involute system cannot be used for wheels having less than 30 teeth without rounding the corners because otherwise there will be a tendency for the corner of the tooth to gouge into the flank of the tooth with which it works.

On the other hand, all involute teeth of the same pitch and angle of obliquity will work together correctly,

COMPLETE ALLIS-CHALMERS MORTISED SPUR GEAR

even though the centers be not exactly the same distance apart, while in the cycloidal in order to work together correctly they must be made with the same rolling circle and must be set with centers at such distance apart that the pitch circles will roll together or the action will not be correct. For interchangeable gears, the tendency is toward the use of the involute tooth, but for heavy transmission work the cycloidal tooth is better adapted on account of the greater thickness at the root.

The surface of the tooth above the pitch line is called the face and the length is called the addendum. The surface below the pitch line is called the flank and the length is called the dedendum.

Pitch

CIRCULAR pitch or circumferential pitch is the distance from center of one tooth to the next measured along the pitch circle, while the diametral pitch from which gears are usually named, is the number of teeth divided by the diameter of pitch circle in inches. This is a shop name which is really a mistake, for diametral pitch is properly the diameter of the pitch circle divided by the number of teeth, but common custom has transposed this.

The pitch to be used depends on the power to be transmitted and also on the size of the gear. A high diametral pitch means a fine tooth well fitted for small powers and small wheels, while for large transmission gears the low number diametral pitch is suited. The relation between circumferential pitch and diametral pitch is that circumferential pitch equals 3.142 divided by the diametral pitch.

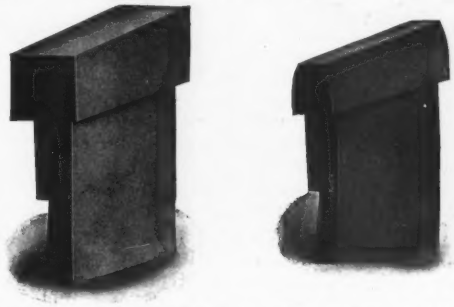
Proportions

PROPORTIONS of teeth vary greatly with different designers but the system most widely used in the United States is that recommended by Wilfred Lewis, whose investigations on the subject of gearing have become classic and the proportions are as follows: The thickness of the tooth is 0.48 of the pitch, the space between teeth is 0.52 of the pitch. The length of the addendum is 0.31 of pitch, the length of the dedendum 0.39 pitch. These values are for machine molded gears. For cut gears the thickness is made 0.5 of the pitch and the space 0.5 pitch. For mortise gears having wood cogs in one gear and iron cogs in the other to avoid noise, the cogs are made 0.6 of the pitch and the space 0.4 of the pitch on the mortise wheel; the iron cogs are 0.4 pitch and spaces 0.6 pitch.

Speed limits for gearing under favorable conditions are as follows: For cast-iron spur gears 1,800 ft. a minute, for helical gears 2,400 ft. a minute; for mortised gears 2,400 ft., steel gears 2,600 to 3,000 ft., special machine cut wheels, 3,000 ft. The thickness of the rim below the root of the tooth is usually made equal to the thickness of the tooth for light gears and equal the length of the tooth for heavy work; the proportions for hubs and arms can be proportioned by the same rules as for pulleys.

Load and Horsepower

FOR the load permissible and the horsepower permissible in gears, the rules given by Lewis are as follows: Considering that the load is carried upon one tooth, that it is distributed across the entire width of the tooth and is carried at the extreme end, the working load in pounds



ROUGH AND FINISHED MORTISE TOOTH, ALLIS-CHALMERS CO.

is then equal to the safe stress of the material times the circular pitch in inches, times the width of the face in inches, times a factor which depends on the form of the tooth. This factor varies with the number of the teeth and with the system of tooth outline, but for the involute with 15 deg. obliquity and for the cycloidal system it is as follows:

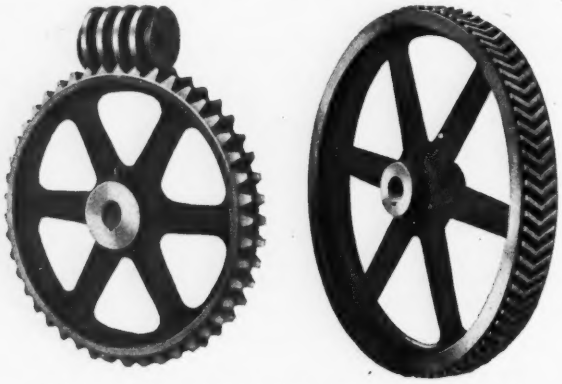
For 12 teeth, 0.067; 15 teeth, 0.075; 16 teeth, 0.077; 18 teeth, 0.083; 20 teeth, 0.090; 23 teeth, 0.094; 25 teeth, 0.097; 27 teeth, 0.100; 30 teeth, 0.102; 34 teeth, 0.104; 38 teeth, 0.107; 43 teeth, 0.110; 50 teeth, 0.112; 60 teeth, 0.114; 75 teeth, 0.116; 100 teeth, 0.118; 150 teeth, 0.120; 300 teeth, 0.122; rack, 0.124.

The safe working stress varies with the speed of the teeth at the pitch line and for 100 ft. a minute or less is taken as 8,000 for cast iron and as 20,000 for steel. At 200 ft. a minute the values are, cast iron 6,000, steel 15,000; at 300 ft., cast iron 4,800, steel 12,000; at 600 ft., cast iron 4,000, steel 10,000; at 900, cast iron 3,000, steel 7,500; at 1,200, cast iron 2,400, steel 6,000; at 1,800, cast iron 2,000, steel 5,000; at 2,400, cast iron 1,700, steel 4,300.

Using the same assumptions and values, the horsepower which may be transmitted by any gear becomes the revolutions per minutes times the diameter of the gear in inches, times the safe working stress, times the circular pitch in inches, times the width of the face in inches, times the tooth factor, times 0.000007933.

In order to get quiet running at high speeds for such uses as gearing down from electric motors to other shafts, rawhide pinions are found desirable, and for these the New Process Rawhide Co., of Syracuse, N. Y., gives the following rule for the horsepower: Multiply the pitch diameter in inches by the circular pitch in inches, by the width of the face in inches and by the revolutions per minute and divide by 850. The formula applies only when the circular pitch is not greater than 1.65 in. and gives a horsepower about ¾ that for cast-iron teeth.

Where the pitch is large so that but 1 or 2 teeth are in action at a time, in order to secure steady running



HELICAL AND WORM GEARS, GEO. V. CRESSON CO.

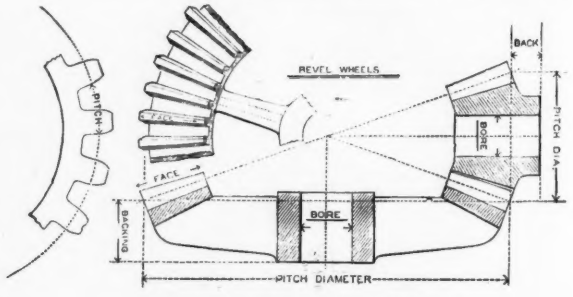
step gears are sometimes used. In these the gear is divided up into small widths and these are turned with respect to each other, giving each tooth the appearance of a series of gears twisted in skew form. When these steps are made very narrow we have the inclined faced gear or spiral gear, which when used alone produces an end thrust on the shaft and to avoid this end thrust 2 spirals inclined in opposite directions are usually used together, giving the herringbone form. The angle of tooth with a line parallel to the axis of the gear is usually made 30 deg.

A development of this twisted gear is the case in which a single tooth is wrapped several times around a cylinder, thus forming a screw thread with a cross section the shape of a gear tooth and then in place of the wheel turning about its axis the cylinder turns about its axis, forcing the meshing gear forward by screw action. In this form it is known as worm gearing, and while older authorities have considered that worm gearing was necessarily inefficient, F. A. Halsey has shown that with proper proportions and design this need not necessarily be so. The worm gear has found application in the power plant field in crane and elevator practice for use on the winding drums, the advantage being that with a double drive on the winding drum having the spirals faced in opposite directions, there is no end thrust on the worm shaft and by the very shape of the gearing there is no tendency for the worm to slip and permit the load to fall, even should the brake fail to operate.

If run at too high a speed, even with light load, the worm will heat because it is of small diameter and has but little chance to dissipate the heat generated. A velocity of rubbing surfaces of 200 to 300 ft. a minute has been found as high as desirable where continuous working is necessary.

Halsey's investigations of worm gearing show that with an angle between the thread and the line perpendicular to the axis of the worm of less than 9 deg., the worm gear drives have not proved satisfactory, while with this angle greater than 12 deg. the drives have been successful even when heavily loaded. With a velocity of 100 ft. per minute at the pitch line he finds the efficiency to be 82 per cent with an angle of 10 deg. and 91 per cent with an angle of 40 deg. The strength of the worm drive is governed by the strength of the gear rather than by that of the worm, and the strength of the gear teeth and the power which the gear will transmit can be figured the same as for a spur gear.

Bevel gears are arranged for axes that run at right angles to each other and Angle gears where the axes form some other than a 90-deg. angle. The teeth are all mounted on the surfaces of cones instead of the surfaces of cylinders and are, therefore, tapered. The circular



OUTLINES OF BEVEL GEARS

pitch is measured at the outer end of the cone which theoretically is a portion of a sphere but in practice is taken as a conical surface at right angles to the pitch surface of the gear. The form of the teeth is first developed on the base of the cone and the taper is then found by drawing lines from the developed outline of the tooth to the intersection of the axes of the pitch cones.

Lewis has developed a formula for the working load on the teeth of bevel gears which is the same as the one for spur gears with the addition that the value as found

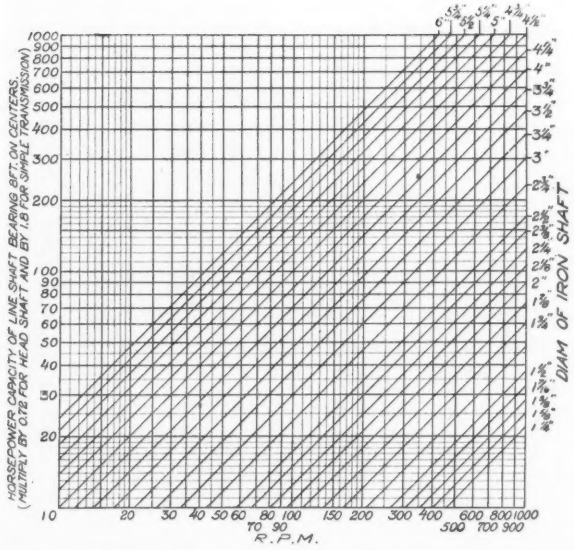
HORSEPOWER OF SPUR GEARS

(PER REVOLUTION PER MINUTE AND PER INCH OF BREADTH.)

Pitch in Inches.	Diameter of Wheel.																				
	ft in 6	ft in 9	ft in 1 0	ft in 1 3	ft in 1 6	ft in 1 9	ft in 2 0	ft in 2 3	ft in 2 6	ft in 2 9	ft in 3 0	ft in 3 6	ft in 4 0	ft in 4 6	ft in 5 0	ft in 5 6	ft in 6 0	ft in 7 0	ft in 8 0	ft in 9 0	ft in 10 0
1	·006	·009	·012	·015	·018	·021	·024	·027	·030	·033	·036	·042	·048	·054	·060	·066	·072	·084	·096	·108	·120
1¼	·007	·011	·015	·019	·022	·026	·030	·034	·037	·041	·045	·052	·060	·067	·075	·082	·090	·105	·120	·135	·150
1½	·009	·013	·018	·023	·027	·031	·036	·040	·045	·050	·054	·063	·072	·081	·090	·099	·108	·126	·144	·162	·180
1¾	·010	·015	·021	·026	·032	·036	·042	·047	·052	·058	·063	·073	·084	·094	·105	·115	·126	·147	·168	·189	·210
2	·012	·018	·024	·030	·036	·042	·048	·054	·060	·066	·072	·084	·096	·108	·120	·132	·144	·168	·192	·216	·240
2¼	..	..	·027	·034	·040	·047	·054	·061	·067	·073	·081	·094	·108	·121	·135	·148	·162	·189	·216	·243	·270
2½	..	..	·030	·038	·044	·052	·060	·068	·074	·082	·090	·104	·120	·134	·150	·164	·180	·210	·240	·270	·300
2¾	..	..	..	·041	·049	·057	·066	·074	·082	·091	·099	·115	·132	·148	·165	·181	·198	·231	·264	·297	·330
3	..	..	..	·045	·054	·063	·072	·081	·090	·099	·108	·126	·144	·162	·180	·198	·216	·252	·288	·324	·360
3¼	..	..	..	·049	·058	·068	·078	·088	·097	·107	·117	·136	·156	·175	·195	·214	·234	·273	·312	·350	·390
3½	..	..	..	..	·064	·072	·084	·094	·104	·116	·126	·146	·168	·188	·210	·230	·252	·294	·336	·378	·420
3¾	..	..	..	..	·067	·078	·090	·101	·112	·124	·135	·157	·180	·202	·225	·247	·270	·315	·360	·405	·450
4	..	..	..	..	..	·084	·096	·108	·120	·132	·144	·168	·192	·216	·240	·264	·288	·336	·384	·432	·480
4¼	..	..	..	..	..	·039	·102	·115	·127	·140	·153	·178	·204	·230	·255	·280	·306	·357	·408	·460	·510
4½	..	..	..	..	..	·034	·108	·122	·134	·148	·162	·188	·216	·242	·270	·297	·324	·378	·432	·486	·540
4¾	..	..	..	..	..	..	·111	·126	·142	·157	·171	·199	·228	·256	·285	·315	·342	·399	·455	·512	·570
5	..	..	..	..	..	..	·120	·135	·150	·165	·180	·210	·240	·270	·300	·330	·360	·420	·480	·540	·600
5½	..	..	..	..	..	..	..	·148	·164	·182	·198	·230	·264	·296	·330	·362	·396	·462	·528	·594	·660
6	..	..	..	..	..	..	..	·162	·180	·198	·216	·252	·288	·324	·360	·396	·432	·504	·576	·648	·720

for spur gears is multiplied by the ratio of the small diameter of the bevel to the large diameter. The power transmitted by a bevel gear will be the working load times the velocity of the pitch line in feet per minute (taken midway of the gear face), divided by 33,000.

An approximate rule for the horsepower of gears based on a stress of 1500 lb. per square inch is that the horsepower equals the pitch diameter in inches times the pitch in inches, times the width of the teeth in inches,


HORSEPOWER CAPACITY OF LINE SHAFT BEARING 8FT. ON CENTERS.
(MULTIPLY BY 0.72 FOR HEAD SHAFT AND BY 1.8 FOR SIMPLE TRANSMISSION)
DIAM. OF IRON SHAFT
TO 90 R.P.M.
500 700 900

HORSEPOWER OF TURNED IRON SHAFTING

For line shafting, from which power is taken at intervals and bearings are 8 ft. apart, the horsepower of an iron shaft is equal to the cube of the diameter times the revolutions per minute divided by 90. For head shafting multiply this result by 0.72, and for transmitting power which is not taken off at intervals the horsepower found by this rule and the above diagram should be multiplied by 1.8. Line shafting is seldom less than 2 or more than 4½ in. in diameter, the smaller values in the above diagram therefore apply to jack shafts and the larger values to head shafting.

DATA OF COTTON DRIVING ROPES

DIAM, IN.	WT. PER FT. LB.	BREAKING STRENGTH, LB.	SAFE LOAD LB.	DIAM. OF SMALLEST PULLEY, IN.	CENTER TO CENTER OF ROPES, IN.
¾	0.15	2,600	106	22	1⅛
⅞	0.20	3,500	144	26	1¼
1	0.26	4,600	190	30	1½
1¼	0.40	7,200	294	37	1¾
1½	0.58	10,400	426	45	2⅛
1¾	0.79	14,000	576	52	2½
2	1.04	18,400	750	60	2¾

WEIGHT PER FT. = 0.87 × DIAM.² BREAKING STRENGTH = 4600 × DIAM.²
WORKING LOAD = 160 × DIAM.² SMALLEST WHEEL = 30 × DIAM.

HORSEPOWER OF COTTON ROPES

VELOCITY IN FT. PER MIN.	DIAM. OF ROPE, IN.						
	¾	⅞	1	1¼	1½	1¾	2
1,000	3.16	4.30	5.67	8.76	12.7	17.2	22.3
1,200	3.77	5.12	6.76	10.4	15.1	20.5	26.6
1,400	4.36	5.93	7.83	12.1	17.6	23.7	30.8
1,600	4.94	6.74	8.86	13.7	19.9	26.9	34.9
1,800	5.50	7.47	9.86	15.3	22.1	29.9	38.8
2,000	6.03	8.20	10.8	16.7	24.3	32.8	42.6
2,200	6.55	8.90	11.8	18.2	26.4	35.6	46.3
2,400	7.04	9.56	12.6	19.5	28.3	38.3	49.7
2,600	7.50	10.2	13.4	20.8	30.1	40.7	53.0
2,800	7.92	10.8	14.2	21.9	31.8	43.0	55.9
3,000	8.31	11.3	14.9	23.0	33.4	45.2	58.7
3,200	8.69	11.8	15.6	24.1	35.0	47.2	61.4
3,400	9.01	12.2	16.2	25.0	36.2	48.9	63.6
3,600	9.29	12.6	16.7	25.8	37.4	50.5	65.7
3,800	9.53	13.0	17.1	26.4	38.4	51.8	67.4
4,000	9.75	13.2	17.5	27.0	39.2	53.0	68.9
4,200	9.91	13.5	17.8	27.5	39.8	53.8	70.0
4,400	10.0	13.6	18.0	27.8	40.3	54.4	70.7
4,600	10.0	13.7	18.0	27.9	40.4	54.6	71.0
4,800	10.1	13.7	18.0	27.9	40.5	54.7	71.1
5,000	10.0	13.6	17.9	27.7	40.2	54.4	70.7
5,200	9.9	13.5	17.8	27.5	40.0	54.0	70.0
5,400	9.8	13.2	17.4	27.0	39.5	53.0	69.0

Above values are horsepower per rope. Maximum power at 4800 ft. per minute; economical range 4000 to 5400 ft. per minute. Velocity = Diam. of sheave in feet × 22/7 × r. p. m.

CURVES FOR HORSEPOWER OF BELTING.

A = Single leather on pulleys under 8 in. diam., also 3-ply balata.

C = Single leather on pulleys 8 in. to 36 in. diam.

D = Single leather on pulleys over 36 in. diam., also 3-ply rubber.

D = 4-ply canvas.

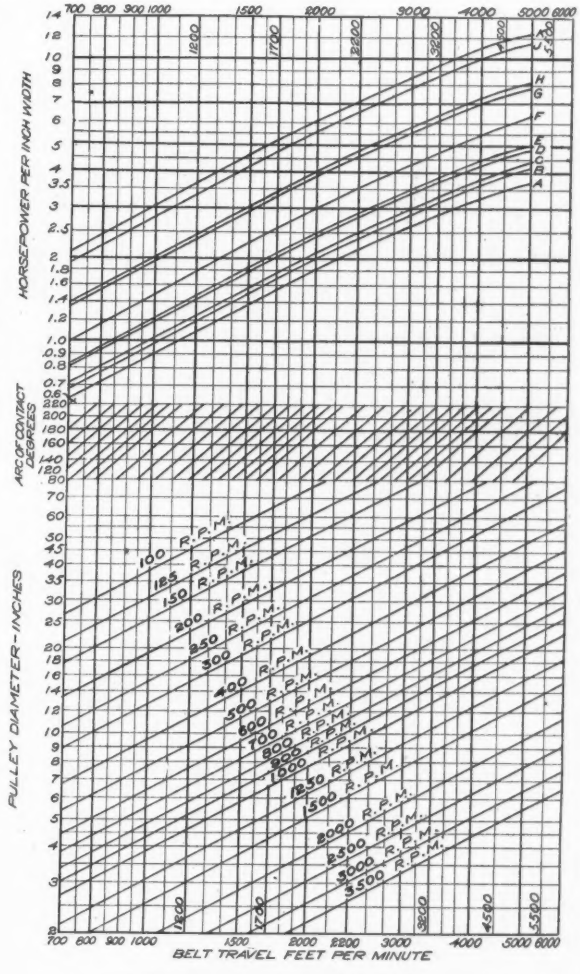
F = Double leather on pulleys under 14 in. diam., also 6-ply canvas.

G = Double leather on pulleys 14 in. diam. and over, also 8-ply canvas.

J = Triple leather, also 1 in. link leather, also 8-ply rubber.

H = ¾-in. link leather, also 6-ply rubber.

K = 10-ply canvas.



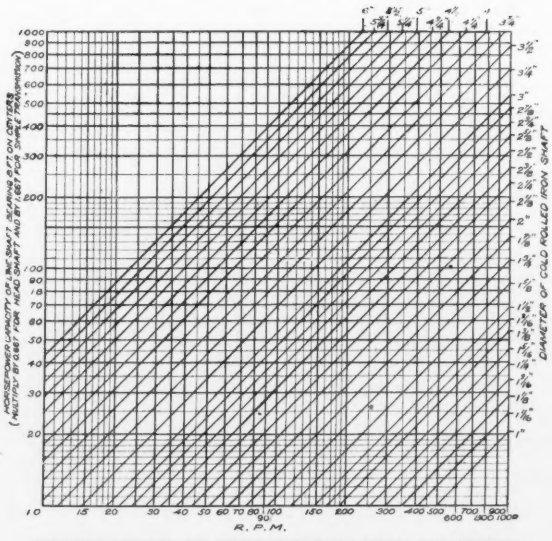
HORSEPOWER DIAGRAM FOR BELTS

From the pulley diameter at the left, trace horizontally to the diagonal r. p. m. line; then vertically to the 180-deg. horizontal; then along the diagonal to the horizontal representing the arc of contact; then vertically to the curve for the kind of belt to be used; then horizontally to the horsepower scale. Multiply by the inches width to get the horsepower; or divide total horsepower to be transmitted by the horsepower scale reading to get width of belt required.

Choose pulley diameter and speed to give a velocity not over 4500 ft. per min.

Allowable Tension on Belts: Single leather, 60 lb. per inch wide; double leather, 105 lb.; triple leather, 150 lb. Rubber, 3 ply, 45 lb.; 4 ply, 65 lb.; 5 ply, 85 lb.; 6 ply, 105 lb.; 7 ply, 125 lb.; 8 ply, 145 lb. Canvas, 4 ply, 40 lb.; 6 ply, 60 lb.; 8 ply, 80 lb.; 10 ply, 100 lb.

HORSEPOWER OF BELT ONE INCH WIDE									
	LEATHER						FIBROUS		
DIAM. OF PULLEY	BELT SPEED FT. PER MIN.	SINGLE LEATHER	DOUBLE BELT	TRIPLE LEATHER BELT 6 PLY RUBBER	½" LINK BELT	1" LINK LEATHER BELT 6 PLY RUBBER	4 PLY CANVAS	6 PLY RUBBER	BALATA 9 PLY
INCHES	AT 1000 R.P.M.								
2	520	0.473							
2.5	650	0.591							
3	780	0.718							
3.5	900	0.818							
4	1,050	0.955					1.05		0.955
4.5	1,170	1.06					1.17		1.06
5	1,310	1.19			2.62		1.31		1.19
5.5	1,430	1.30			2.86		1.43		1.30
6	1,560	1.42	2.48		3.12		1.56		1.42
6.5	1,700	1.55	2.70		3.40		1.70	2.05	1.55
7	1,820	1.65	2.89		3.64		1.82	2.19	1.65
7.5	1,940	1.76	3.08		3.88		1.94	2.34	1.76
8	2,080	2.26	3.30		4.16	5.65	2.26	2.51	2.26
9	2,350	2.56	3.73		4.70	6.38	2.56	2.83	2.56
10	2,610	2.85	4.18		5.22	7.09	2.85	3.14	2.83
11	2,880	3.13	4.56		5.75	7.83	3.13	3.47	3.13
12	3,140	3.41	4.98		6.28	8.53	3.41	3.78	3.41
13	3,400	3.69	5.39		6.80	9.24	3.69	4.09	3.69
14	3,670	3.99	7.05		7.33	9.97	3.99	4.42	3.99
15	3,940	4.28	7.57		7.88	10.7	4.28	4.74	4.28
16	4,180	4.54	8.04		8.36	11.4	4.54	5.03	4.54
	AT 100 R.P.M.								
18	480	0.522	0.983	1.09	0.96	1.31	0.522	0.578	0.522
20	520	0.565	1.00	1.18	1.04	1.41	0.565	0.626	0.565
22	580	0.630	1.12	1.57	1.16	1.58	0.630	0.699	0.630
24	630	0.684	1.21	1.70	1.26	1.71	0.684	0.759	0.684
26	690	0.740	1.33	1.86	1.38	1.87	0.740	1.06	0.740
28	730	0.793	1.40	1.98	1.46	1.98	0.793	1.12	0.793
30	790	0.858	1.52	2.14	1.58	2.15	0.858	1.22	0.858
32	840	0.912	1.62	2.27	1.68	2.28	0.912	1.29	0.912
34	918	0.989	1.75	2.46	1.82	2.47	0.989	1.40	0.989
36	950	1.03	1.83	2.57	1.90	2.58	1.03	1.46	1.09
38	990	1.19	1.90	2.68	1.98	2.69	1.20	1.52	1.19
40	1,040	1.25	2.00	2.82	2.06	2.83	1.26	1.60	1.25
42	1,100	1.32	2.12	2.97	2.20	2.99	1.33	1.69	1.32
FEET									
4	1,260		2.42	3.40	2.52	3.42	1.65	1.94	1.52
4.5	1,410		2.71	3.81	2.82	3.84	1.71	2.17	1.70
5	1,570		3.02	4.25	3.14	4.27	1.91	2.42	1.89
5.5	1,730		3.68	4.67	3.46	4.70	2.10	2.66	2.08
6	1,880		4.00	5.08	3.75	5.11	2.28	2.89	2.26
6.5	2,020		4.30	5.46	4.03	5.49	2.45	3.11	2.43
7	2,190		4.66	5.92	4.37	5.96	2.66	3.37	2.64
7.5	2,350		5.00	7.12	4.70	6.38	2.85	3.62	2.82
8	2,510		5.34	7.60	5.02	6.83	3.04	3.86	3.02
9	2,820		6.00	8.55	5.63	7.67		4.33	3.39
10	3,140		6.68	9.52	6.28	8.54		4.83	3.78
11	3,460		7.36	10.5		9.41		5.32	4.16
12	3,780		8.04	11.5		10.3		5.81	4.55
14	4,420		9.39	13.4		12.0		6.80	5.32
16	5,040		10.7	15.3		13.7		7.75	6.06
18	5,680		12.1	17.2		15.5		8.74	6.84
20	6,280		13.4	19.1		17.1		9.67	7.56


HORSEPOWER CAPACITY OF BIG SHAFT, BEARING 8 FT. ON CENTERS
(MULTIPLY BY 0.667 FOR HEAD SHAFT AND BY 1.667 FOR SIMPLE TRANSMISSION)
DIAMETER OF COLD ROLLED IRON SHAFT
R. P. M.

HORSEPOWER OF COLD ROLLED IRON SHAFTING

For line shafting, with bearings 8 ft. apart and where power is taken off at intervals the horsepower of the shaft is equal to the diameter cubed times the revolutions per minute divided by 90. For head shafts, multiply this result by 0.667 and for simple transmission where power is not taken at intervals the result given by the above rule should be multiplied by 1.667. The values given in the above diagram for shafting above 4 in. in diameter apply particularly to head shafts, and those below 2 in. to jack shafting.

CORRECTIONS FOR ANGLE OF BELT CONTACT

ARC OF CONTACT DEGREES	CORRECTION FACTOR	ARC OF CONTACT DEGREES	CORRECTION FACTOR
220	1.12	140	0.87
210	1.09	130	0.83
200	1.06	120	0.79
190	1.03	110	0.75
180	1.00	100	0.70
170	0.97	90	0.65
160	0.94	75	0.50
150	0.91	60	0.40

BELTING RULES

Horsepower = Value from table × angle of contact factor × width × r. p. m. ÷ (100 or 1000).

Width Needed = Horsepower × (100 or 1000) ÷ (value from table × angle of contact factor × r. p. m.).

Pulley Diameter: For leather, diameter in feet = 3 × belt thickness in inches. For rubber, 4 ply, use 23-in. diam. or larger; 5 ply, 30-in.; 6 ply, 36-in.; 7 ply, 42-in.; 8 ply, 48-in. For canvas 4 ply, use 4-in. diam., or larger; 6 ply, 6-in.; 8 ply, 8-in.; 10 ply, 10-in.

Lacings: For small belts ¼-in. thong; 4-8-in. belts, ⅜-in. thong; 8-15-in. belts, ½-in.; over 15-in., ¾-in. Holes, ¾ in. from sides, 1st row ⅞ in. from end, 2nd row 1¾ in. from end. For 3-in. belt use 4 holes; for 6-in., 7 holes; for 10-in., 9 holes.

For Endless Splice: For leather, up to 10 in. wide, make 10 in. long; from 10 to 18 in. wide, make length = belt width; above 18 in., make length 18 in.

Rubber: For 8 in. belts, use 24 in. length; for 12 in., 36 in.; for 16 in., 32 in.; for 24 in., 36 in.; for 30 in., 40 in.; for 48 in., 48 in.

DATA OF MANILA ROPE

DIAM IN.	WT. PER FT. LB.	BREAKING STRENGTH LB.	LARGEST WORKING TENSION, LB.	LENGTH OF SPLICE FT.	DIAM. OF SMALLEST SHEAVE, IN.	MAXIMUM R.P.M. FOR 5000 FT. PER MIN.	APPROX. TENSION WT. LB.
¾	0.20	4,000	112	8	30	650	95
⅞	0.26	5,400	153		35	550	125
1	0.34	7,100	200	10	40	475	175
1⅛	0.43	8,900	250	10	45	425	225
1¼	0.53	10,900	310	10	50	400	275
1⅜	0.65	13,200	380	12	54	350	325
1½	0.77	15,700	450	12	60	320	375
1⅝	0.90	18,500	530	12	67	290	425
1¾	1.04	21,400	610	12	70	270	550
2	1.36	28,000	800	14	80	240	650
2¼	1.73	35,400	1,000	14	90	210	750

WT. PER FT. = 0.34 × DIAM.² BREAKING STRENGTH = 7100 × DIAM.²
MAXIMUM TENSION = 200 × DIAM.² DIAM. SMALLEST SHEAVE = 40 × DIAM.

DIAM. ROPE IN.	VELOCITY, FEET PER MINUTE										
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6000
¾	2.3	3.3	4.3	5.2	6.0	6.6	7.2	7.3	7.4	7.3	6.9
⅞	3.0	4.5	5.9	7.0	8.2	9.0	9.6	9.8	10.0	9.6	9.0
1	4.0	5.9	7.7	9.2	10.6	11.8	12.7	12.9	13.0	12.7	12.0
1⅛	5.0	7.5	9.7	11.8	13.5	14.9	16.0	16.3	16.7	16.5	15.3
1¼	6.3	9.1	12.0	14.3	16.7	18.5	20.0	20.2	20.7	20.1	18.9
1⅜	7.5	10.8	14.4	17.4	20.0	22.1	23.7	24.5	24.6	24.0	22.3
1½	9.0	13.5	17.4	20.7	23.0	26.3	28.7	29.0	29.3	28.6	26.7
1⅝	10.5	15.5	20.1	24.3	27.9	30.8	32.9	34.1	34.3	33.3	31.0
1¾	12.3	18.0	23.6	28.2	32.7	36.4	38.5	39.4	40.3	38.7	36.0
2	16.0	23.2	30.6	36.8	42.5	46.7	50.0	51.7	52.8	50.6	47.3
2¼	20.0	29.6	38.6	46.6	53.6	59.2	63.6	65.8	66.3	64.4	60.3
2½	25.0	36.6	47.7	57.3	66.0	71.2	78.0	80.0	81.0	79.0	73.8

HORSEPOWER OF MANILA ROPE

Figures of above table are horsepower per rope. Maximum power at 5000 ft. per min.; economical range of working 4000 to 5500 ft. Sag of rope on driving side at power given in table; for pulleys, 40 ft. apart centers, 4 in.; for 60 ft., 10 in.; for 80 ft., 17 in.; for 100 ft., 2 ft.; for 120 ft., 2 ft. 11 in.; for 140 ft. 3 ft. 10 in.; for 160 ft., 5 ft. 1 in.

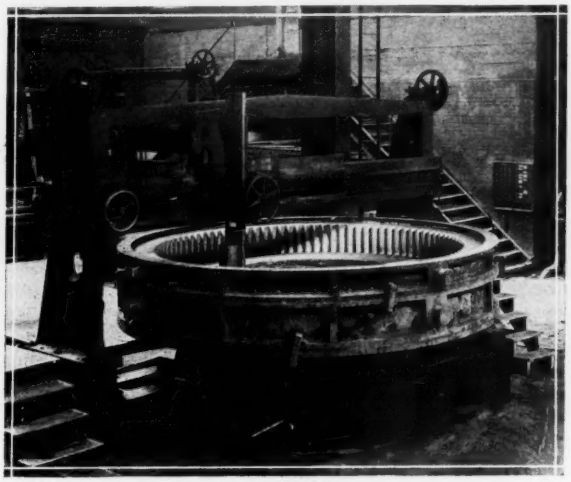
Horsepower diagram will be found in a later issue.

times the revolutions per minute, divided by 1000. This assumes that ½ the load falls on each tooth, that there is uniform bearing across the breadth of the tooth and that the tooth is of ordinary proportions. The table of horsepowers given herewith is based on this rule.

MACHINE MOLDED GEARS

Mesta Machine Co., Pittsburg, Pa.

THE METHOD OF building gears that has been in use by the Mesta Machine Co. for many years does away entirely with the inaccuracies of pattern molded castings, such as warping of the pattern, the taper or draft necessary to take the pattern from the sand, irregularities in the mold caused by rapping, as well as the



MESTA GEAR MOLDING MACHINE

difficulty in making a pattern which has all teeth identical and accurately spaced on the rim of the gear.

The machine consists of a substantial base which carries a revolving horizontal table, 2 vertical struts, and an adjustable cross rail. The turning of the table and spacing of the teeth are accomplished by a gear drive attachment to a worm and wheel. The desired pitch of the gear is then obtained by changing the ratio of the gear drive. To the traveling head which is mounted on the cross rail is fastened the form of a single tooth of the gear desired.

As soon as one tooth is molded the tooth block is backed off with the traveling head and the table rotated the amount of the circular pitch. Tooth block is then returned to the proper pitch line against a stop, and the process repeated until the molding is completed. The mold made by this method is necessarily circular in form as it is the figure of revolution, and the teeth being machine divided are accurately spaced. This same method is applied with equal success and accuracy to bevel, spur, worm and helical gears with either internal or external teeth and of any size and pitch desired.

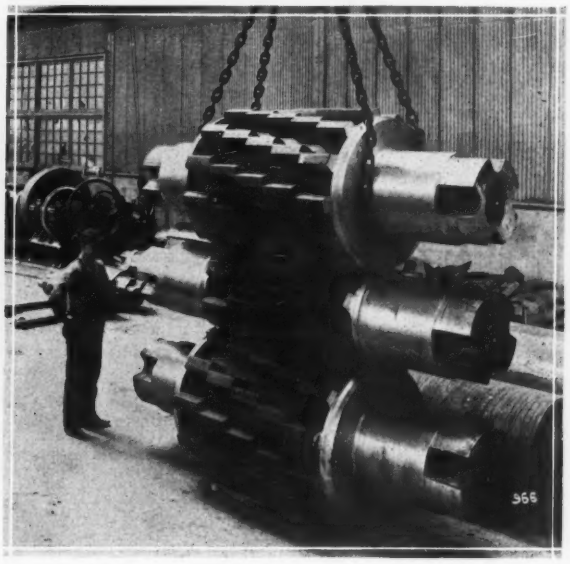
An illustration of the possibilities of this machine is given in the view No. 2 of a five step staggered pinion or set of pinions built for a large sheet mill, weighing 100,000 lb. To mold these pinions by the old time pattern process would be impossible.

Practically no limit to size, face or pitch is placed on the possibilities of this method of building gears.

The increasing demand for higher speed and greater accuracy in gearing to meet the enormous tonnage requirements of modern built machinery has led the Mesta Co. to install new gear planers with capacity for larger gears than it has been possible to cut in the past. One of these planers will cut teeth in a spur gear 30 ft. in diameter, or a bevel gear up to 24 ft. in diameter.

All gears whether machine molded or cut are made from either air furnace melted iron, open hearth cast steel, or where special service or strength is required, of nickel steel, vanadium steel or any of the alloys that may be necessary to give the casting the qualities peculiar to the service required.

Special annealing ovens have been designed and used for annealing gears arising from the need of having the temperature increased equally at all points of the casting to avoid unnecessary strains which otherwise would warp



STAGGERED PINIONS, MACHINE MOLDED

the casting. In fact to meet the various needs of heavy service, higher speed and accurate work demanded by modern practice compels the manufacturer to recognize that every step in the manufacture of transmission making must be guarded by every precaution known to the best engineering practice.

DESCRIPTION OF MUSLIN GEARS AND PINIONS

By J. Riddell

THE general subject of gears and pinions is very broad and interesting to those engaged in mechanical work; and especially to those held responsible for designs of important pieces of apparatus. Many improvements have been made during the past 25 or 30 years in the shape of teeth and methods of cutting. The higher development of machine tools, automobile gear boxes, and gear transmission boxes, for various purposes, have brought about wonderful improvements in the design, manufacture and treatment of this class of apparatus.

The material which enters into gears and pinions has had as much consideration as the design and shape of the gears and teeth. Since the days when steel castings could be made sound and at reasonable cost, many gears have been made of that material, but much trouble was encountered in making heavy trains of steel cast gears run together properly on account of severe cutting, unless they could be properly lubricated.

Some few experiments were attempted in casting pinions of brass chills. This was done to save labor of turning and cutting and to cheapen the pinions generally. This also was a fallacy, as it was necessary to cast the pinions with a shrink head, which was returned to the brass foundry at half the original cost. The saving of labor in turning and cutting the teeth was a mere trifle when we consider automatic machinery used for this purpose. Rawhide had a bad habit of warping and shrinking out of shape; fiber would not stand the moisture.

At the Schenectady plant of the General Electric Co., where thousands of gears and pinions are used for almost as many purposes, every known material has been used to overcome some special difficulty. The last experiment was with pinions made of muslin.

We had a severe case of gear trouble to correct where cast iron, steel, bronze, rawhide and fiber were used with varying degrees of success, until one day in desperation the boss millwright of the plant had a pinion made up of muslin. That is now some 2 years ago, since which time we have had absolutely no trouble with gears on this particular machine.

I might mention here that the machine referred to is one located in a blacksmith's shop where there is considerable dirt, grease and smoke in the atmosphere. The pinion when first placed in service had a thick smear of grease applied to it, and as far as I can understand this is the first and last grease put on this particular pair of gears. The grease seems to penetrate the muslin, and the muslin seems to protect itself by taking a thin film of steel or iron from the gear with which it runs. This particular job showed such encouraging results that it was thought worth while to extend the use of the muslin gears, until today we have several hundred pinions.

One of the earliest commercial uses to which these pinions was put was in a cotton mill down South where cast-iron gears were used first but had to be abandoned on account of the noise. Fiber and rawhide also gave some trouble. Silent chain was tried but had to be abandoned. It looked for awhile as if gears could not be used on this outfit, when a sample cloth pinion was sent and tested out for this purpose. The first 2 or 3 months I had flattering reports on the action of the pinion, and it solved the noise problem. Several other pinions were furnished this particular mill, and up to date we have heard nothing further from them, so I assume that they are still giving good results.

As to the construction of gears made of this material, it is only necessary to pile up a sufficient number of muslin disks to get the desired thickness, after which they are put under a hydraulic press at about 11 or 12 tons pressure per square inch. They are securely riveted between 2 steel disks, with the rivets or screws well out toward the teeth to prevent dishing. There is considerable elasticity in this material which tends to force the disks apart, which must be resisted by a sufficient number of screws or rivets. In our case we have found it best to thread completely through the 2 flanges and the muslin and use screws threaded the whole length. This to a certain extent tends to clamp the whole fabric together with the disks, after which the screws are slightly riveted on the end to prevent working loose.

It is necessary to have these steel flanges of considerable thickness to prevent dishing. It is not necessary, however, in the majority of cases, or unless the gear is to run as an idler, to have a metal center, as we have found that a key cut through the muslin and flange will have sufficient strength for any driving purpose. It is necessary in applying these gears to be sure that the wheel with which they run be accurately and smoothly cut. It is not advisable to use them in connection with gears which have been worn so that the teeth have become mutilated or have lost their correct curve.

MACHINE MOLDED GEARING

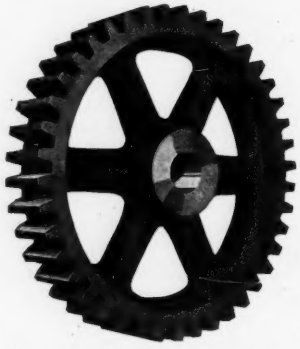
A. Plamondon Mfg. Co., Chicago

THE MOST IMPORTANT item in the transmission of power by gears—so that they will run quiet and smooth—is that all the teeth shall be of exact size and proper shape, accurately spaced and on a true circle or pitch diameter of correct size.

These conditions are practically impossible to attain in molding gears from full patterns, which warp and shrink, and even if it were possible to make and keep a perfect pattern the molder necessarily has to rap the pattern loose so as to have draft or taper on the teeth in order to draw it from the mold; all of which tends to distort the form of the wheel and teeth. These changes together with the imperfections in the pattern are the cause of so many noisy and poor running gears causing unnecessary vibration and loss of power.

In the process of machine molded gears as made by the A. Plamondon Mfg. Co. of Chicago, these defects in patterns and molding are eliminated by the use of special machinery which accurately divides or spaces the teeth by means of cut worms and gears, and the shape and size of the teeth are made uniform by molding each tooth separately from an accurate single tooth pattern which is drawn from the mold by mechanical means so that it does not require rapping or draft.

These machines are constructed so all kinds and sizes of gears such as spur, bevel, single and miter gears, also mortise wheels and pinions, can be molded on them. By the use of these machines a great saving in time and



PLAMONDON MOLDED GEAR

labor can be effected on account of the small amount of pattern work needed, which is an important item on the larger sizes of gears.

The company is one of the pioneer machine molded gear makers in Chicago, and is specially equipped to make standard gearing of all kinds on short notice.

IN FUTURE the Vonnegut Machinery Co. will operate at 43-45 South Meridian St., Indianapolis, Ind., the business heretofore known as the Machine Department of the Vonnegut Hardware Co. The organization will include Messrs. Anton Vonnegut, Charles Rassman and C. B. Williamson, and will carry a full line of machine tools and power transmission machinery, including the Dodge line of apparatus, American steel split pulleys, Yale & Towne chain hoists and a full line of standard pulleys, hangers and shafting equipment.

VARNISHED CAMBRIC CABLE

General Electric Co., Schenectady, N. Y.

CABLES FOR DIRECT or continuous current are generally single conductor and the voltage seldom exceeds 600. For working pressure 600 volts or less the thickness of the insulation is determined largely by mechanical considerations, and therefore no difference is made between cables for 600 volts, 250 volts or 125 volts, the usual standard voltages.

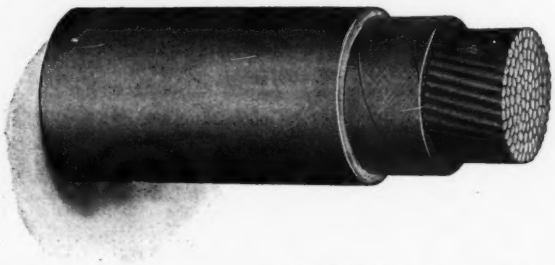


FIG. 1. SINGLE CONDUCTOR 2,000,000 C. M. CABLE.

In many installations 3-phase alternating current motors are used with the following standard voltages: 110, 220, 440, 2200, 4400, 6600.

Such an installation requires 3 conductors in each circuit and, in many cases for convenience, and always

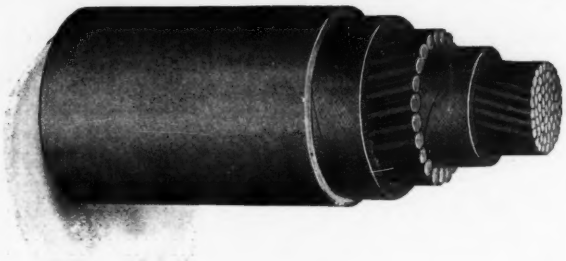


FIG. 2. TWO CONDUCTOR, 1,000,000 C. M. CONCENTRIC CABLE FOR LARGE FEEDERS ON SINGLE PHASE A. C. CIRCUITS OR ON LOW. TENSION D. C. SYSTEMS

where installed in conduits, these 3 conductors are combined in 1 3-conductor cable.

A new type called varnish cambric insulated cable, especially suitable for this power transmission, was brought out some 6 yr. ago, is briefly described in the following paragraphs:

FIG. 3. NO. 1 B. & S. G. FLAT TWIN LEADED JUTE AND ASPHALT CABLES FOR SINGLE PHASE WORK.

A separator of treated paper, cloth or rubber is applied to the copper core to prevent any possible action of the varnished cambric film on the copper, and over this separator are taped strips of fabric which have been multiple coated with special insulating varnish. A single thickness of this coated material requires from 7000 to 12,000 volts to puncture it in 5 seconds, depending upon the number of films or coats which have been applied to the cloth. Between the tapings a thin layer of plastic, nonhardening, insulating compound is applied. This compound prevents the varnished cambric tape from unwrapping when the cable is cut, yet permits the adjoining layers of varnished cambric to slide upon one another, ensuring that the insulation remain concentric when the cable is bent. This filling compound prevents the capillary absorption of moisture between the tapings, seals any possible flaw in films, and prevents air spaces. The special varnish used and the insulating compound which is applied between the layers are both manufactured by the General Electric Co.

FIG. 4. FOUR CONDUCTOR 500,000 C. M. CABLE FOR MEDIUM AND LOW TENSION TWO PHASE SYSTEMS.

After the application of a number of layers of taping sufficient to secure the required thickness of insulation, the core is finished by cotton braiding and weatherproofing, or asbestos braiding and fireproofing.

The layers of varnished cambric tape are slightly lapped and so there is no reduction in the thickness of the insulation on the outside of the cable when it is bent.

All finished cables are tested at a potential of 2½ times the working pressure. Varnished cambric cables

FIG. 6. THREE CONDUCTOR 2/0 CABLE, LEADED, WITH JUTE AND ASPHALT JACKET AND BAND STEEL ARMOR, FOR USE AS THREE PHASE FEEDING CABLE BURIED DIRECT IN THE EARTH WITHOUT ADDITIONAL PROTECTION.

can be bent to a radius 6 times their own diameter without reducing their ability to stand up under the guaranteed test pressure.

In soldering, cambric insulation is not easily injured by the heat, nor does the insulation of the cable absorb moisture during the process of jointing. Oil of the kind generally used in switches and in the lubrication of generators does not injure varnished cambric-covered cables. The cables can, therefore, be run directly into oil switches and oil filled transformers, or can be used as leads to generators.

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THE ISSUE

This is it. The result of much hard work and research; representing the best of modern practice. Its rules aim to provide ample strength to give security and long life of the installation. These are worth getting even at some increase in first cost over an equipment that "would do." Where there has been departure from old standards, it is because the latest knowledge shows that heavier apparatus pays.

Where specific acknowledgment was possible for data or articles it has been made. For other information which has been woven into the general discussions and for the assistance of those individuals and firms who have furnished material and illustrations we would express our appreciation and thanks at this time. Not all the matter gathered could be used. Some came too late to put into shape; some was duplicated; some was, of necessity, held for a future issue. The burden of choice lay on the editors; it has been a hard task, but we have tried to keep in mind at all times "What will you, our readers, find most helpful?" We transmit it to you in the hope that it will give you more power and prosperity.

STEAM PIPE TRANSMISSION

Spite of the fact that piping practice gets itself finally settled about once in so often, just as frequently something new condition arises which calls for a readjustment of ideas and a resettlement of practice. The change from moderate pressure steam to high pressure, bringing with it expansion difficulties and necessity for greater strength, made a change. The use of superheated steam increased expansion troubles and brought other difficulties in the way of disintegration of material in fittings which had not been anticipated; but, on the other hand, it removed somewhat of condensation difficulties and permitted the use of smaller piping so that it had advantages as well as difficulties.

Because of the fact that with the earlier piping and fittings and in the somewhat haphazard method of making joints there was trouble with pipe lines, transmission power by means of a steam pipe got into bad favor and long lines were avoided as much as possible. With the better practice demanded by the use of superheated steam, stronger fittings, tighter and more durable flange joints and greater care in laying out of piping systems, we are finding that transmission even over considerable distances by means of high-pressure steam somewhat superheated is as efficient as any method yet devised.

Where the power is to be subdivided at the end of transmission, a limitation is placed by the inefficiency of the small steam prime mover, but as a matter of transmission pure and simple from boiler to engine, the power to be used in a large lump at the end of transmission, piping can give a good account of itself for distances up to 1,000 ft.

M. B. URQUHART, northwestern manager for the Keystone Lubricating Co., Philadelphia, Pa., manufacturers of Keystone Grease, informs us that the company has moved its offices from the Century Building into the new First National Bank Building, Denver, Colo., where he will be pleased to receive friends and customers. He also extends an invitation to any of the out of town boys who may be visiting the City of Lights to drop in.

NEWS NOTES

FOR THE WINTER of 1910 and 1911 the N. A. S. E. Association No. 37 of Dayton, Ohio, has laid out an interesting educational program as follows: Bituminous Coal, Anthracite Coal, Crude Oil and Fuel, Natural Gas, Steam Boilers, Furnaces and Firing, Smoke Stacks, Boiler Feed Water, Heaters, Open and Closed, Boiler Feed Pumps, Piping, Valves and so forth. Under each heading a series of questions is asked for discussion by the members, the whole making a complete analysis of the different topics. The program has been arranged by the educational committee, consisting of Thos. F. Synnett, chairman; L. W. O'Brian, R. H. Holbrook, E. Hill, W. V. R. Coon and J. A. Hultzren. It is certainly an interesting and thorough outline for a season's study.

THE MANAGEMENT of the Pittsburg Engineering Agency, Pittsburg, has formed a business company trading under the name of The American Service Co., which will immediately take over the Inter-State and Pan-American representation of the Associated Bureau Service comprising the several bureaus of Technical References, American Trade Catalogs, Engineering and Industrial Research.

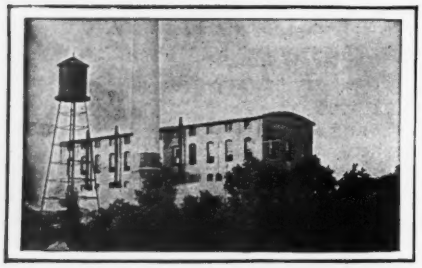
Offices have been opened in the Bessemer Building, where in addition to the Associated Bureau Service a technical reference library and contract proposal exhibit quarters will be maintained for the general convenience of the public. The first named bureaus are maintained in the interest of the technical professions and industrial corporations gratis. The chairman of the executive committee invites inquiries.

VELLUMOID for gaskets, pump packings and other uses, formerly manufactured by the Vellumoid Paper Co., is now made by the Newton Mfg. Co. of Worcester, Mass. The new company has taken over the entire business of the Vellumoid Paper Co., including real estate, machinery, patents and all assets, and will continue business at the present plant, which is at Greendale, near Worcester, Mass.

JEFFREY MANUFACTURING Co. has opened a new office at Atlanta, Ga., in the Fourth National Bank Building, where a stock of Jeffrey chains and catalogs will be carried in hand. D. C. Rose, formerly with the Dodge Mfg. Co., will be manager of the new office, which is the 10th branch office in the United States. There are also over 100 Jeffrey agencies in the principal cities in the United States and the leading commercial centers all over the world. In all these agencies as well as in the branch offices the Jeffrey elevating and conveying machinery is handled and installations are planned for handling and distributing material for every possible purpose.

JOHN D. SELLS, general manager of the Royersford Foundry and Machine Co., has just returned from a three months' business trip to Europe, where he went to extend their connections for the sale of the Sells Roller Bearing and the general line of power transmission machinery made by his firm. They have opened a branch at 149 Queen Victoria St., London, E. C., in charge of Theodore Butler. He reports business at home and abroad as exceedingly good, for in spite of having erected an additional building 50 by 50 ft. the company is compelled to run 20 hr. a day in order to meet the demand for its product.

WILLIAM C. HENNING has resigned as president and treasurer of the Durable Wire Rope Co. of Boston, Mass., and accepted the position of secretary and treasurer of the A. Leschen & Sons Rope Co. of St. Louis, Mo.



Power Apparatus

In Shop and Market

New Ideas in Making, Buying and Selling

THE REEVES VARIABLE SPEED TRANSMISSION

IN this device the principle is 2 pairs of spline-mounted disks fitted on 2 parallel shafts. The illustrations show clearly the workings of the different parts.

Figure 1 represents disks on the driving shaft separated to admit the belt to the smallest driving diameter and the disks on the driven shaft correspondingly together so that the belt assumes the greatest driving diameter, thus propelling the driven shaft at its maximum speed.

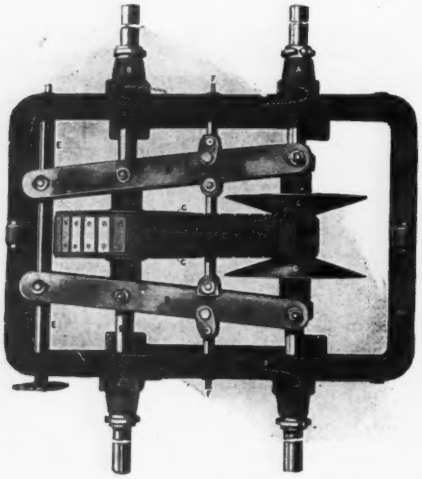


FIG. 1. REEVES VARIABLE SPEED TRANSMISSION IN POSITION TO GIVE SLOWEST DRIVING SPEED

FIG. 2. ROLLER THRUST BEARING

FIG. 3. PARTS OF ROLLER THRUST BEARING

The inner faces of the disks form a V-shaped groove into which is fitted a specially designed belt, having its bearing surface on the edges instead of the bottom, as with the ordinary belt. One set of disks acts as driver, the other as driven, and as the disks are actuated so that the belt assumes a large diameter on one pair of disks, it at the same time assumes a smaller diameter on the opposite pair of disks, thus increasing and diminishing the speed of the driven shaft, and giving any speed between the 2 extremes on the variable shaft.

The main cast-iron frame of the transmission is of rectangular form, made in 2 pieces, and provided with hangers cast solid with the frame. The shaft bearings are ring-oiling, and are removable and all parts are accessible for inspection and adjustment. These bearings are all made reversible, so that if at any time it is desired to change the machine from floor to ceiling it is only necessary to reverse these parts.

In the smaller size transmission the disks are driven by mean of double keys mounted in the shafts on which they slide when speed adjustment is being made. The hubs of the disks bear against specially constructed roller thrust bearings, thus reducing the friction to the least possible amount. In the larger size transmissions a heavy driving collar is keyed to the shaft midway between the disks. Two steel pins are fixed in the outer part of this collar, bronze bushed bearings are placed in the disks, through which steel shafts work and act as driving pins. These driving pins are located a sufficient distance from the shaft to give great leverage, and are large enough to provide ample bearing surface.

The belt is made by bolting hardwood blocks of precisely the same length and thickness to the belt body, the ends of these blocks being given the proper angle to fit against the disks, and are capped with leather.

The same principle of construction is used in the larger sizes as in the smaller ones, except that a heavy cast-iron base is provided and the strength of the parts throughout increased in proportion to the size of the machine. In the larger size transmissions the speed changing device is operated by hand or power, according to the demand of the particular installation. The important feature of the construction of this transmission is the roller thrust bearing, as shown in Figs. 2 and 3, one of which is placed outside of each disk.

The bearing consists of a thrust bearing yoke, oiler, cap screw with washers, 2 steel collars, one split bronze cage with steel rollers. In the smaller size

transmissions, one steel collar is bored considerably larger than the shaft, and is carried by the thrust bearing yoke. The other collar is bored to the same size of the shaft and is carried by the shaft against the disk hub. In the larger size transmissions the collars are of the same dimensions. The distinctive feature of this bearing is the spherical shape of the outer ends of the steel rollers. These are so designed that the ends of the rollers fit against the interior walls of the thrust bearing yoke, and hold the rollers in perfect alinement regardless of wear on these parts. The bronze cage acts as a separator only. In all sizes of transmissions the cages and steel rollers may be removed from the shaft without disturbing any of the other parts, the cage being made split for this purpose.

The installation of this transmission is a matter of interposing it between the motive power and the machine operated, in the same manner as an ordinary countershaft; either placing it on the floor or suspending it from the ceiling as desired. After the transmission is located the belt is run from the line shaft to the constant speed shaft of the transmission, and from the variable speed shaft of the transmission to the pulley on the machine to be driven.

In order to meet the varying conditions of speed control, the transmission is manufactured in 14 different sizes, and in 7 ranges of speed, the smallest size transmitting 2½ hp., and the largest size 150 hp.

A TRIBUTE FROM LONDON

IN Timber and Wood-Working Machinery of London, a correspondent, J. M. N., has the following to say in regard to treatment of belts:

"Ever since the introduction of machinery, leather belting has been used for transmitting power in a great variety of ways. In almost every climate, and under all sorts of conditions, we have seen belts which have to run through water from morning till night; others, again, have to work in factories and sugar refineries, where the temperature is very high. In some places the belts are saturated with oil, in others they are hard and dry with the dust and heat, etc. The mere fact that leather has been so largely used for so many years gives it high place as a power transmitter. But, that it is not infallible under any circumstance, can be easily proved by the numerous dressings on the market, expressly manufactured for leather belts to prevent slipping, etc. Some of them are very good, and some not so good.

"Personally, I have tried all sorts of belt dressings; resin, soap, varnish, tallow, castor oil, etc. While I have read of numerous other preparations, the strangest of all was sand. No doubt, if you had someone always throwing a handful of sand between the belt and the pulley you would prevent slipping, but what about the sand tearing up the belt and the pulleys, eh? I fancy the cure would be worse than the slipping. But what suits one particular trade is useless in another, as the conditions are so totally different.

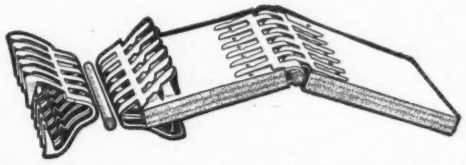
"While a liquid dressing of sticky nature would be all right for engineers and printers, it would be of no use at all in a sawmill, as the dust would adhere to it and form lumps on the pulley, and so make it slip more. Resin, again, will certainly help your belts to pull a heavier load, but it is injurious if frequently used. I find castor oil is by far the best, as it keeps the belts pliable, and lets them hug the pulleys closer. It has to be used sparingly to get the best results; too much will make a belt slip more than ever. Neatsfoot oil is another good remedy for slipping belts, but it should be applied warm to the back of the belt with a brush, to get the best results.

"Now that Balata belts are so largely used, on account of their lightness and freedom from stretch, perhaps it would not come amiss to know that oils are usually injurious to them, instead of being beneficial. I have several hundred feet of Balata belting under my care at present, and after trying several preparations, I find that Stephenson Bar Belt Dressing, Green Label Brand for rubber belts, is by far the best, only it has to be carefully used; a slight application is all that is necessary to make a belt pull its full load without slipping.

ALLIGATOR STEEL BELT LACING

THIS lacing, manufactured by the Flexible Steel Lacing Co., of Chicago, which is shown in application and in detail by the illustration is adapated for use on leather, rubber, cotton or canvas stitched belting and requires for its application no tool but a hammer. It forms a hinge joint, the pin being of rawhide or sectional steel as desired. Teeth on either side of the belt which are staggered with respect to each other enter the belt by driving, and each tooth has 2 prongs, the longer one at the end which penetrates the belt and is bent over, while the shorter one enters the body of the belt but does not go through. Both prongs enter the belt so that the pull is against the edges of the steel rather than the flat, thus avoiding cutting off fibres of the belt.

An advantage with the Alligator is the ability to put the lacing on the ends of the belt at any time and to place the belt on the pulleys afterward and insert



DETAILS OF ALLIGATOR LACING AND A COMPLETE JOINT

the pin. By using short distance pieces, a belt may be cut at once to the length which it will finally have and at distance pieces inserted which can be replaced by a shorter one as the belt stretches.

This lacing is made up in lengths of 12 in. with indentations on the connecting bar between prongs so that it can be broken off for any width of belt. Also this indentation allows of flexibility so that over heavily crowned pulleys the bar may be bent or broken without weakening the hold of the lacing on the belt.

Tests of the Alligator lacing show that when properly applied the belt will be broken before the lacing will pull out. A gauge pin is furnished with each box of lacing so that it will be applied at the right distance from the end of the belt to give a good hinge.

LEAKING POWER

ANOTHER "leak," which is different from that due to belting, in that the loss of power from imperfect transmission is a "negative leak," while that due to rod packing is a "positive leak," though, of course, the ultimate effect is the same, is that due to poor rod packing.

In other words, the use of packing that maintains a fixed and unvarying pressure on the rod is really a

"brake" on the engine, because during nearly 50 per cent of the piston travel, while the steam is acting on the "head" side of the piston, no pressure but the low pressure of the exhausted steam is exerted on the packing at the "crank" end of the cylinder, where the packing is, except during the time of compression.

When the steam is acting on the "crank" end, it is obvious that the pressure exerted by the packing should be sufficient to withstand the maximum steam pressure,

A COIL OF DANIEL'S WEDGE PACKING, SHOWING THE CONSTRUCTION

but this condition exists only during the "period of admission," after which the pressure steadily diminishes as expansion takes place, hence the pressure of the packing should be variable. Where the engine is compound or condensing, or compound and condensing, the conditions are more complicated, and a perfect piston rod packing should meet them all.

Scientific tests, conducted by a corps of prominent mechanical engineers, show that Daniel's P. P. P. Rod Packing fulfills all these requirements, in that the pressure it exerts on the rod, whether to resist steam or atmospheric pressure, is in exact proportion to the requirement, whether it be 300 lb. or but 3 lb.

This adjustment is secured by the "Daniel idea" of 2 sliding wedges and a compressible cushion. The theory and the proof of its correctness are set forth in "The Story of Some Friction Tests," a treatise on packings and friction, issued by the Quaker City Rubber Co.

CHARCOAL IRON BOILER TUBES

AMONG the charcoal iron forges and plate mills of half a century ago the Parkesburg Iron Co., of Parkesburg, Pa., has a unique record in that it is the only one in existence today which has preserved and improved the old methods of manufacture and is producing charcoal iron exclusively.

FIG. 1. INTERIOR OF PARKESBURG IRON CO.'S WORKS

In order to correct the confusion which sometimes arises as to what charcoal iron really is, it is well to state that in the furance the charge consists as in the past of pig iron from which the silicon has been oxidized, or of clean finely divided wrought and steel scrap. Any stock containing elements detrimental to the finished product are by chemical analysis readily eliminated.

In the process of manufacture, charcoal and the iron stock are put into a furnace, where by means of a hot blast every part of the metal is melted and sinks to the hearth. This gives a basic slag and the carbon, silicon and manganese are practically eliminated, also the sulphur and phosphorous are very largely decreased.

Each drop of metal is encased in a filiament of cinder, and, as in the puddling process, is brought to nature by the reducing flame and collects into a ball consisting of pure fibrous iron, subdivided by a network of cinder. The greater part of hot cinder is then shingled out of the iron under the hammer, and the result is a bloom of strictly pure charcoal iron. The mills of the Parkesburg Co. have always been engaged in the manufacture of purely charcoal iron, and their product prior to 1900 was consumed by different tube mills for charcoal iron tubes.

Until 1908 the output of the Parkesburg Mill amounted to 20,000 tons annually, but during the summer of 1908 an entirely modern tube mill was erected by the Parkesburg Iron Co. which, since that time, has been turning out tubes made from Parkesburg Charcoal Iron skelp, the present capacity being about 360 tons a week, or about

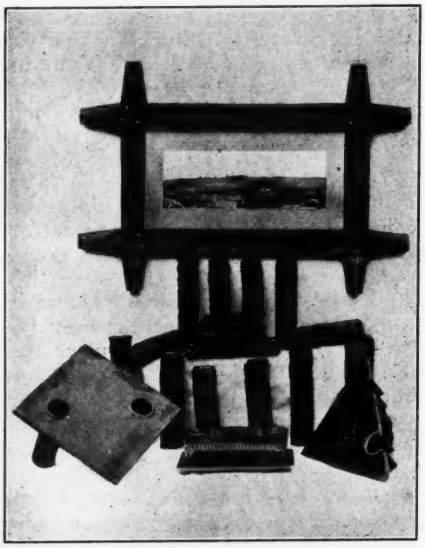


FIG. 2. TESTS ON PARKESBURG CHARCOAL IRON TUBES

18,000 2-in., No. 11 tubes. These tubes are given the most careful inspection and have remarkably few blisters, run true to gage, and are of so soft a nature that they bead over the flue sheet with the greatest ease, and rarely require rerolling after installation.

As a comment on the value of charcoal iron tubes, over 80 per cent of the railroads in the United States continue to use these tubes, many of them exclusively, and in stationary boiler works for general and special purposes there is a growing demand for the charcoal iron tubes.

The Parkesburg Co. makes also special arch pipe of identical iron with the former Allison special, a quality which is the safest on the market and is a protection to the lives of engineers and firemen.

As to the life of iron tubes, on several railroads the average mileage of charcoal iron tubes is 100,000 miles without safe ending, after which safe ends can be applied indefinitely.

The interior view of the tube mill gives an idea of the resources which are available for careful manufacture and inspection, and the second illustration, which shows some tests of Parkesburg Charcoal Iron tubes under pressing, flattening, bending and kneading, gives a very clear idea of the quality of material employed in their manufacture. Charcoal iron has the advantage that it has long life when exposed to the influence of impure and of extra pure water. It is free from pitting due to its low manganese; it welds readily when it is desirable to put on new tube ends; it is free from crystallization under vibration or shock, which is an advantage when beading the end of the tube. These charcoal iron lap-welded boiler tubes are made with outside diameter from 1½ to 6 in. in standard gage, and can be furnished in any gage on special request.

THE KENEHAN BELT FASTENER

The Kenehan Steel Belt Fastener Co., Cleveland, O.

THESE FASTENERS ARE of the hook form, made from a specially rolled steel with the points arranged in 2 lines so as to come staggered across the

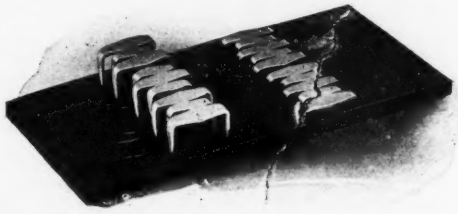
KENEHAN STEEL BELT FASTENER AND METHOD OF APPLICATION

belt. They are made with 2, 3 or 4 points, for different widths of belts and are applied as indicated in the illustration.

BRISTOL STEEL BELT LACING

The Bristol Co., Waterbury, Conn.

THIS FASTENER, which is made in various sizes, has staggered points entering the belt in double rows, insuring the greatest strength to the joint with the least disturbance of the belt material. It is made in different weights and widths and with different



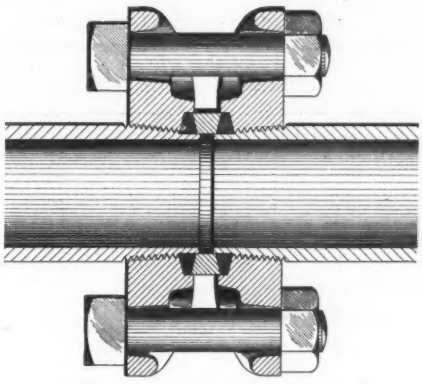
BRISTOL STEEL LACINGS FOR JOINING ALL KINDS OF BELTS

styles of prongs for various classes of belting. The illustration herewith shows the method of using this lacing and the application to belts. For certain kinds it is found desirable to use the lacing with the points in a single row rather than staggered, so that both types are made.

OSBORNE PIPE JOINT

Osborne High Pressure Joint and Valve Co., Chicago, Ill.

THE OSBORNE PIPE-JOINT also brings out a new principle, in that no joint is made on the thread of the pipe or between the 2 faces of the flanges. It is made between the union ring and the pipe ends by the compression of the wedge shaped packing, making a continuous metal casing, except for the small difference in area (about 1/64 in.) between the cylindrical end



OSBORNE HIGH-PRESSURE JOINT

of the pipe and the internal surface of the union ring. The threads merely hold the parts together, and leaks, if any, may be stopped with a monkey wrench, without putting the line out of service.

The packing is of suitable material for the intended service and is so boxed in by metal that packing blowouts are impossible.

Absolute alignment is not necessary to make a joint, nor is any welding, facing or soldering required.

TRADE NOTES

EDGE MOOR IRON CO. has recently been installing a large number of big boiler plants throughout New England and vicinity. Among them 4 350-hp. boilers have been furnished to the Dwight Mfg. Co., Chicopee Falls, Mass., and a short distance away a 500-hp. boiler is being installed for the Fisk Rubber Co. The Dwight Co. boilers are to be cared for by the large chimney described in the December issue.

THE AMERICAN STEAM PUMP CO., Battle Creek, Mich., recently received the following letter, which speaks well for the operation of Marsh pumps: "Replying to your inquiry of the 14th inst., beg to advise that we have been using two of your Marsh Boiler Feed Pumps for about twelve years, taking water from our heater at 211 deg. F., and pumping it into our boilers with perfect satisfaction. The cost of up-keep and repairs has been so small as to be scarcely worth mentioning.—Spears Axle Co."

SCULLY'S BULLDOG PULLEY PASTE, made by the Scully Steel & Iron Co., Chicago, Ill., is a paste which is quickly and easily applied to the pulley for the purpose of increasing the holding power and adding to the wear of the belt. It is furnished in closed cans and is applied with a brush to the thickness of 1-16 to ⅛ in., according to the size of the pulley.

IT'S WEARY WORK shoveling coal into the furnace and blowing it out of a pipe joint.

PRACTICAL ENGINEER CLASSIFIED ADVERTISEMENTS

Advertisements in this section are inserted under regular headings at the rates of 40 cents per line. About nine words make a line. No display type allowed, but the first three words may be set in capital letters. Minimum space sold, two lines.

Under classification, "Positions Wanted," advertisements not exceeding four lines will be inserted for subscribers once free of charge.

To insure proper classification, copy must reach this office on or before the 15th of month preceding publication.

Positions Wanted

POSITION WANTED—By young man 21 years of age as hoisting engineer or as stationary engineer in small plant. West preferred. W. F. Judkins, Bow, Mich. 1-1

POSITION WANTED—Engineer would like to take charge of small plant or act as assistant in large one. Have had 7 years' experience. Familiar with the operation of both A. C. and D. C. generators. W. Break, River Rouge, Mich. 1-1

POSITION WANTED—As stationary engineer steam or gasoline engines. Can do own repair work and am machinist and run D. C. dynamos. Have Minnesota license. Moral habits. Address J. L., R No. 3, Box 39, Fairfax, Minn. 1-1

POSITION WANTED—By erecting engineer experienced in installing heating and ventilating machinery and small power plants, open for engagement about Feb. 1st. Reference from former and present employers. Address Box 159, Practical Engineer, Chicago, Ill. 1-1

POSITION WANTED—As engineer in a small plant, or as hoisting engineer. Have had several years' experience. Position in South preferred. Address Box 96, Quitman, Miss. 1-1

POSITION WANTED—As engineer by married man, with present central station four years, has Massachusetts license. Would like position in extreme West. A-1 references. Address Box 687, Foxboro, Mass. 1-1

POSITION WANTED—By young man 26 years of age; 8 years' experience. Corliss, slide valve engines, air compressors, and dynamos. Permanent position wanted. Address Box 157 Practical Engineer, Chicago, Ill. 1-1

POSITION WANTED—Engineer holding third class Massachusetts license wants position. Good mechanic and electrician with power house and lighting experience. Best of references. D. V. Fox, 385 Moody street, Waltham, Mass. 1-1

POSITION WANTED—There are dollars to be saved in the boiler room to dimes in the engine room. A chief engineer who understands boiler room economy from A to Z is open for an engagement. Address 158, care Practical Engineer, Chicago, Ill. 1-1

POSITION WANTED—By steam and electrical engineer. 30 years of age, married, sober and reliable. Have an A. S. of C. education. Am at present master mechanic for electric railroad. Good references. Address Box 154 Practical Engineer, Chicago, Ill. 1-1

POSITION WANTED—As engineer or assistant in electric power or manufacturing plant by strictly sober young man. Had charge of present Hydro-steam electric plant 27 months, and with steam in previous years. Address Box 156, Practical Engineer, Chicago, Ill. 1-1

Help Wanted

WANTED—AGENTS, ENGINEERS PREFERRED, to sell Boiler Cleaning Chemicals. Liberal commissions paid. Continental Chemical Co., Forrest Bldg., Philadelphia, Pa. 1-1

WANTED—AN ENGINEER in each town to sell the best metallic packing for steam, air, gas and ammonia. Write Ideal Metallic Packing Co., South Stillwater, Minn. 5-tf

WE HAVE a stunning proposition for an engineer in every town or city. Little time required. Will not interfere with regular work. Write for particulars. Address Box 136, Practical Engineer. 8-tf

WANTED—SALESMEN CALLING ON power plant trade to sell Ohio Steam Specialties on commission. High class line, liberal commissions. The Ohio Brass Co., Steam Dept., Mansfield, Ohio. 1-1

ENGINEERS AND MECHANICS—To make big money selling Incomparable "ZIZ" Hand Soap. A 10-cent can will instantly remove more dirt and stains from the hands than four cakes of any soap made, and it will not injure the most delicate skin. Small sample free. Byram Mfg. Co., Box 3133, Boston, Mass. 4-tf

Wanted

AGENCIES REQUIRED—AN old established manufacturing firm in London, with a splendid connection among the English and Colonial Railways, is open to make arrangements to manufacture and sell, or to accept an agency for, any really good article likely to be extensively used by railway companies. References would be furnished and required. Communicate to T. N. 310, care T. B. Browne's Advertising Offices, 163 Queen Victoria Street, London, E. C., England. 12-3

For Sale

FOR SALE—A 250 H. P. McEWEN direct-connected engine and dynamo. Engine is 18x18. Dynamo, 150 K.W.—250 volts—600 amperes. Can be seen running. Price, $2,500.00 Send for details to J. L. Lucas & Son, 3 Fox St., Bridgeport, Conn. 1-1

FOR SALE—ONE D. C. 220 VOLT 35 K.W. Western Electric Dynamo, speed 1150. One marble switchboard complete, with ammeter volt meter and reostat with two circuit cables to connect same to dynamo. 1100 ft. No. 000 wire, 750 ft. No. 0—wire, weather proof, good insulation, all in good running order. Write for prices to Pierce Milling Co., Pierce, Neb. 1-3

Patents and Patent Attorneys

PATENTS—H. W. T. Jenner, Patent Attorney and Mechanical Expert, 608 F St., Washington, D. C. Established 1883. I make a free examination and report if a patent can be had and the exact cost. Send for full information. 10-tf

PATENTS—C. L. Parker, late Examiner U. S. Patent Office, Attorney-at-Law and Solicitor of Patents. Patents secured promptly and with special regard to the legal protection of the inventors. Handbook for inventors sent upon request, 186 McGill Building, Washington, D. C. 4-tf

Miscellaneous

EVERY ENGINEER should know about the new system of Vacuum Heating, which can be installed without payment of royalty. Particulars will be cheerfully furnished. T. L. Reeder, 1413 W. Jackson Blvd., Chicago.

$1.50 WILL BUY Castings and all material for neatly designed modern automatic steam engine. Engine has governor and slide valve on cut-off principle with adjustment for wear. Blue prints and instruction sheets 25c. Elgin Wheel & Engine Co., Elgin, Ill. 1-1

Educational

"TELEPHONE TROUBLES" AND HOW to find them, and manual of cost units, New Edition (14th). Price 25c. W. H. Hyde, Telephone Bldg., 183 5th St., Milwaukee, Wis. 1-1